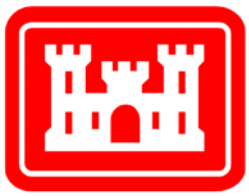
LOUISIANA COASTAL PROTECTION AND RESTORATION
TECHNICAL REPORT

DRAFT

STRUCTURAL PLAN COMPONENT APPENDIX

February 2008



U. S. Army Corps of Engineers
New Orleans District
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Table of Contents

List of Tables

List of Figures

Introduction

The Louisiana Coastal Protection and Restoration (LACPR) effort was charged with evaluating a full range of flood control, coastal restoration and hurricane risk reduction measures. For LACPR, three types of measures were given equal consideration: structural, nonstructural, and coastal restoration.

Structural, nonstructural, and coastal restoration measures are the building blocks of alternative plans for LACPR. An alternative plan is a set of one or more measures functioning together to address one or more planning objectives. Structural measures for LACPR primarily consist of physical structures that reduce surge and wave run-up, such as continuous or ring levees on land connected to floodgates acting as waterway barriers, where necessary.

The first step in the formulation of measures involved extensive public involvement in partnership with the State of Louisiana. The USACE partnered with the State of Louisiana to identify and evaluate hurricane risk reduction strategies for South Louisiana. Through this partnership, the State developed a Master Plan to provide a long-term vision for hurricane risk reduction and coastal restoration. Numerous risk reduction measures were identified during the development of the State Master Plan. The LACPR Plan Formulation Atlas, which can be viewed and downloaded at http://www.lacpr.usace.army.mil/ documents the extensive collaborative identification of the coastal protection and restoration measures for South Louisiana.

The next step in the plan formulation process was the screening and refinement of measures. This *Structural Plan Component Appendix* describes how structural measures were screened and refined to a smaller and more manageable set of options for integration with the nonstructural and coastal restoration components of the LACPR alternatives. The consideration and screening of nonstructural and coastal management features are described in the *Nonstructural Plan Component Appendix* and *Coastal Restoration Plan Component Appendix,* respectively.

The final step in the plan formulation process, combining measures into alternative plans, entailed the consideration of reasonable and efficient integration of structural measures with nonstructural and coastal restoration measures into viable alternative plans. The Technical Report presents the performance of various alternative plans and illustrates tradeoffs between and among plans on specific objectives and overall program goals.

Alternative plans are not limited to those the U.S. Army Corps of Engineers (USACE) could implement directly under current authorities. Structural measures that could be implemented under the authorities of other Federal agencies, State and local entities, and non-government interests have also been considered. For more information on the LACPR Congressional authority, plan formulation strategy and planning objectives, refer to the main report.

Three-Tiered Screening Process

A three-tiered screening process was used to reduce possible structural measures and alignments to a more manageable number for further evaluation and consideration across a range of stakeholder interests.

- **Tier 1** considered preliminary construction costs, constructability, and environmental impacts to screen potential solutions.
- **Tier 2** considered initial hydromodeling results to further screen the number of measures.
- **Tier 3** used six additional criteria to further screen alternatives as shown below in Table 1.

Table 1. Tier 3 Screening Attributes

ATTRIBUTE	DESCRIPTION
Cost Effectiveness	Ratio of present value costs/average annual risk reduction
Present Value Costs	Present value at 2025 for life-cycle costs
Average Annual Flood Damages	With-project damages
Population Exposed	People inundated at inundation frequency
Construction Period	Years required to complete initial construction
Direct Impact – Wetlands	Wetland acreage impacted by proposed levees

For the third tier screening, each structural measure was rated based on these six attributes. In order to have comparable scores for each of these attributes, each had to be normalized or converted to a range of 0-1 where the lower value is preferred.

Details on the hydromodeling results used to screen measures in Tier 2 are contained in Volume 2 (Annex A) of the *Hydraulics and Hydrology Appendix*.

Organization of This Appendix

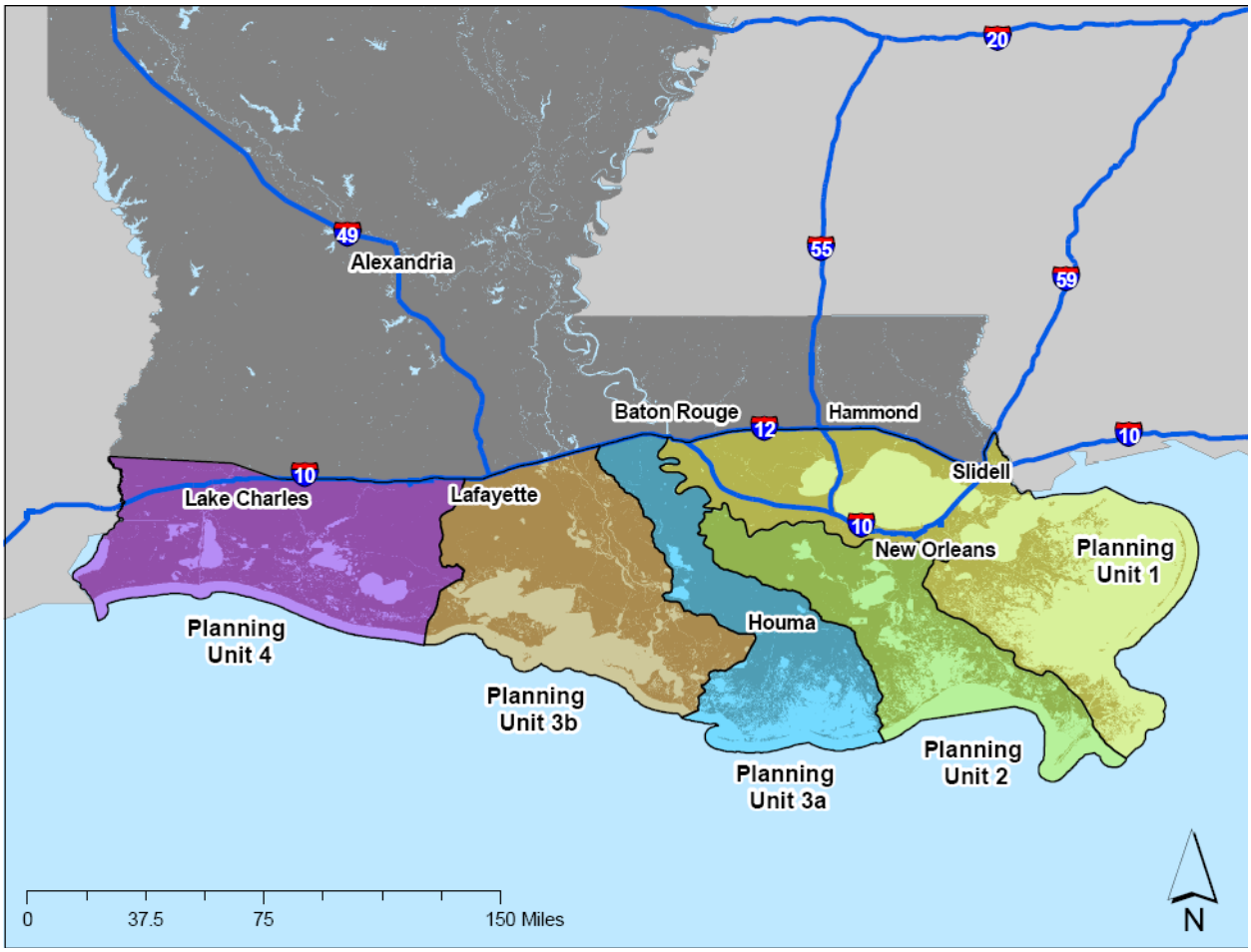
This appendix is organized by planning unit as shown in **Figure 1**. Each of the planning unit sections generally follows the same format:

- Brief description of the planning unit.
- Tier 1 screening – initial screening of structural measures.
  - Codes used to refer to measures screened from the Plan Formulation Atlas.
  - Maps and text describing structural measure variations from the Plan Formulation Atlas.
  - Table(s) and text describing which measures passed/failed the Tier 1 screening and why.
- Tier 2 screening – initial hydromodeling of structural measures.
  - List of remaining formulation issues from Tier 1 screening.
  - Codes used to refer to measures in the Tier 2 and Tier 3 screening.
  - Maps showing reformulated structural alignments.

- Tables and text describing how hydromodeling results were used to screen and/or reformulate measures.

- Tier 3 screening – multi-criteria screening of structural measures.
  - List of remaining formulation issues from Tier 2 screening.
  - Table showing multi-criteria ranking of measures followed by descriptions of why each measure was chosen for the overall LACPR alternatives.
  - Descriptions of each of the measures to be evaluated with the overall LACPR alternatives.

Figure 1. LACPR Planning Area and Planning Units



Planning Unit 1

The following sections provide details on the tiered screening of measures and alignments for Planning Unit 1. Planning Unit 1 is bordered between the (1) Mississippi River to the west, (2) Gulf of Mexico to the south and east, (3) Pearl River on the east, and (4) potential extent of surge inundation to the north. The western border of this planning unit is protected against hurricane surges translating up the Mississippi River by the Mississippi River levees.

Planning Unit 1 is the most densely populated planning unit in coastal Louisiana, containing approximately one million residents, or 47 percent, of the entire planning area's population. The major portion of greater New Orleans is located within the planning unit. The population at risk lives between the Mississippi River east bank levee system and the shoreline areas of Lakes Pontchartrain and Borgne.

There are two basic water bodies that require structural measures to attenuate surge conditions. The first is the Gulf Intracoastal Waterway (GIWW) and its branch channels which includes the navigable reach of the Mississippi River Gulf Outlet (MRGO) and the Industrial Canal. This navigation system bisects East New Orleans. Structural measures would need to address levee improvements and/or navigation gates.

The second water body is Lake Pontchartrain which has two channels connecting it to the Gulf of Mexico – Chef Menteur and The Rigoletes. Structural measures would need to address levee improvements and/or lake closures. The tradeoff for providing structural protection to populated areas along the Lake Pontchartrain perimeter range from closing or limiting flow through the two passes – at least during surge conditions - to creating and/or raising levees and floodwalls between the lake and population areas.

The lower portion of Plaquemines Parish is the area south of metropolitan New Orleans located along the "bird's foot" stretch of land terminating at the mouth of the Mississippi River. Lower Plaquemines Parish has limited opportunity for structural considerations other than ring levees to protect isolated communities and spillways in the Mississippi River levee system to lower the surge elevations. Levee height considerations are impacted by soil foundation strength and land availability for conventional levee width requirement. Screening of structural measures for this area is discussed following the details on Planning Unit 1 and Planning Unit 2.

Tier 1 – Initial Screening of Structural Measures

The Plan Formulation Atlas identified two primary strategies for structural risk reduction in Planning Unit 1. They include a **Lake Pontchartrain Surge Reduction** alignment (**Figure 2**) at the mouth of Lake Pontchartrain and a **High Level** alignment (**Figure 3**). The Surge Reduction alignment proposes to add a levee across the mouth of Lake Pontchartrain with storm gates closing the passes at Chef Menteur and The Rigoletes during a storm event. **Figure 4** displays six different surge reduction alignments (shown as 1-5 and S) and two different alignments within the area known as the Golden Triangle (shown as a and b). The High Level alignment proposes to raise levees on the Southshore of Lake Pontchartrain to a higher level of risk reduction and to add levees on the Northshore of Lake Pontchartrain. Within the two primary strategies, the Plan Formulation Atlas identified 17 variations. **Table 2** describes the codes used in the Plan Formulation Atlas and for Tier 1 screening for measures in Planning Unit 1.

Table 2. Planning Unit 1 Codes from Plan Formulation Atlas used for Tier 1 Screening.

Code	Measure Code Description, e.g. PU1-LP-1a
PU1-	Planning Unit 1
-LP-	Lake Pontchartrain surge reduction alignment
-HL-	High level alignment
-State	Alignment that was part of the preliminary draft State Master Plan
-#	Variations to the primary alignments (if applicable)
a	Golden Triangle alignment at the confluence of the GIWW and MRGO
b	Alignment at the edge of the Golden Triangle and Lake Borgne

Figure 2. Example of a Lake Pontchartrain Surge Reduction Alignment from the Plan Formulation Atlas

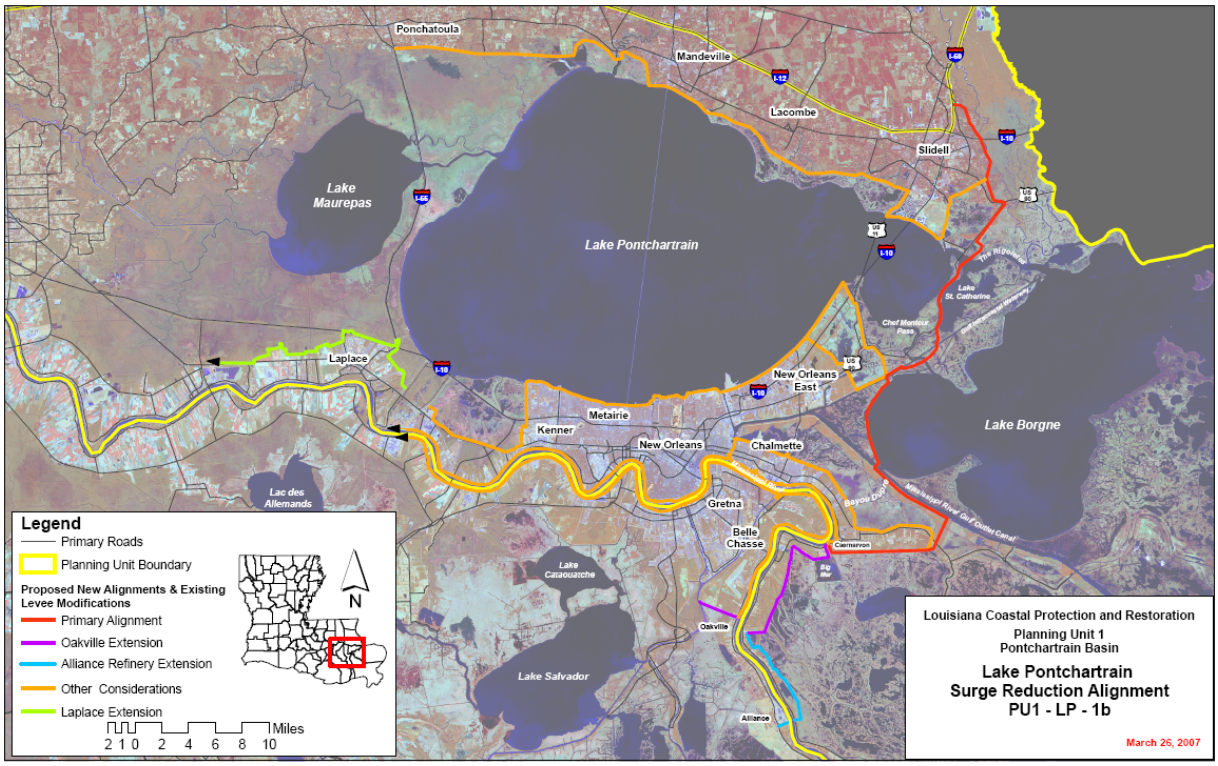


Figure 3. Example of a High Level Alignment from the Plan Formulation Atlas

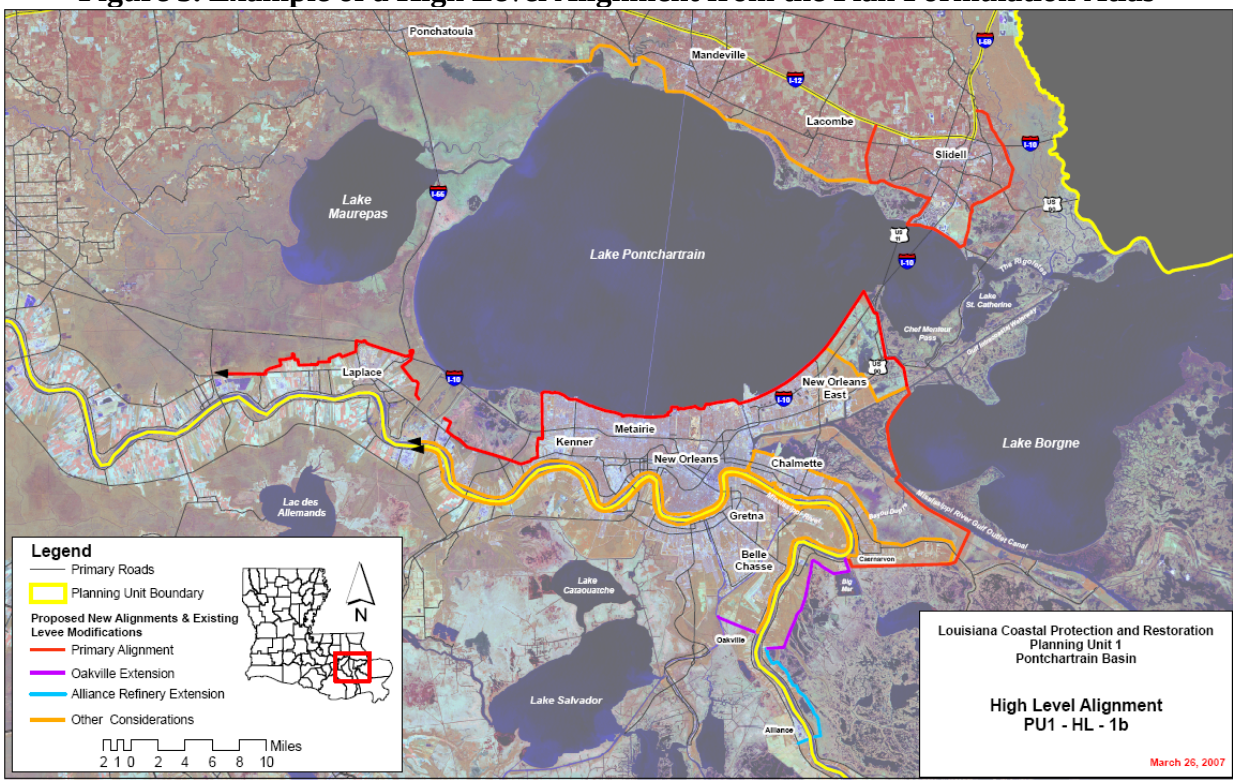
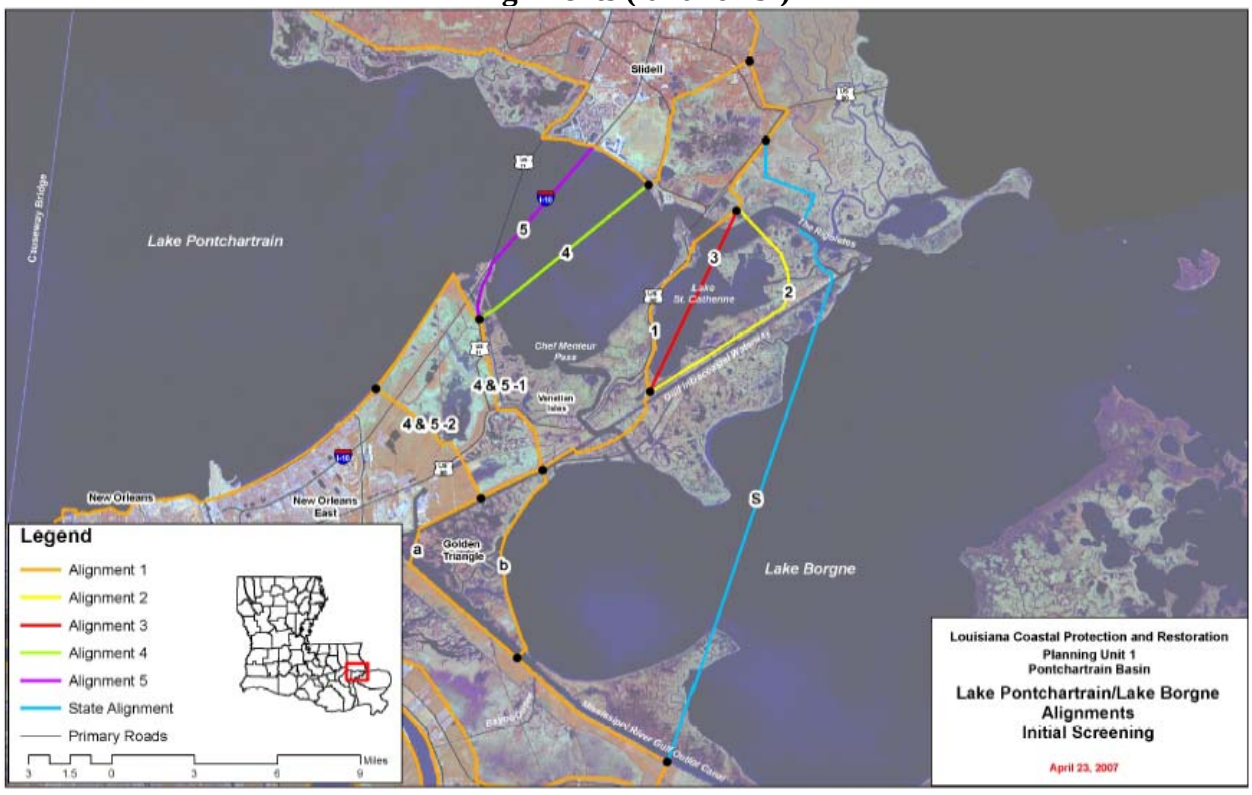


Figure 4. Various Surge Reduction Alignments (1-5 and S) and Golden Triangle Alignments ('a' and 'b')



Cost Considerations

Rough order of magnitude costs were developed for each of the Surge Reduction Alignments and the Golden Triangle alignments. Alignment 'a' refers to the levee alignment that would cross the Golden Triangle wetlands at the confluence of the Gulf Intracoastal Waterway and the Mississippi River Gulf Outlet. Alignment 'a' is part of the baseline conditions scheduled to be in place around 2011. Alignment 'b' follows along the edge of the Golden Triangle and Lake Borgne and would provide a secondary line of defense to Alignment 'a.' **Table 3** shows the initial construction and real estate costs (in $1,000s) for the levee alignments at Lake Ponchartrain and Lake Borgne.

Table 3. Rough Order of Magnitude Cost Estimates for Levee Alignments at Lake Pontchartrain and Lake Borgne in Planning Unit 1

A - Alignment		B - Alignment	
Alignment	**Initial Costs**	**Alignment**	**Initial Costs**
LP-1a	$10,816	LP-1b	$10,051
LP-2a	$10,783	LP-2b	$10,026
LP-3a	$19,980	LP-3b	$19,222
LP-4a1	$26,468	LP-4b1	$25,725
LP-5a1	$26,273	LP-5b1	$25,528

Note: Planning Unit 1 cost estimates assume the levees are 30 feet high and are built from the ground up. The cost estimates for the 'a' alignments would go down if the new 100-year levees being in place are taken into account. Costs assume geotextile levee construction (i.e. traditional construction methods).

Screened Alignments

Table 4 lists the variations of both the Lake Pontchartrain Surge Reduction alignments and the High Level alignments and describes why some alignment variations were eliminated from further consideration at this time. As indicated in **Table 4** alignments 3, 4 and 5 were eliminated from further screening due to the extremely high cost as compared to alignments 1 and 2 which provide similar output.

306 **Table 4. Initial Screening of Planning Unit 1 Structural Measures**
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Measure Code(s)	Pass/ Fail	Comments
PU1-LP-1a and 1b	Pass	These alignments follow Highway 90 along the landbridge. The State screened this measure out because of public opposition (multiple landowners), so it is not included in the State Master Plan; however, the LACPR team felt that the multiple landowner issue is not insurmountable and carried this measure forward into the next screening because of its good soil foundation. Costs for 1a and 1b are same magnitude as for 2a and 2b below (~$10 – 11 billion).
PU1-LP-2a and 2b	Pass	These alignments follow the GIWW/railroad and are essentially the same as those represented in the State Master Plan. Costs for 2a and 2b are same magnitude as for 1a and 1b above ($10 – 11 billion).
PU1-LP-3a and 3b	Fail	These alignments cross Lake St. Catherine and have significant constructability, operability, and environmental concerns. In comparison to alignments 1 and 2 above, alignment 3 has more constructability, operability, and environmental concerns. In addition, the cost is higher (~$19 – 20 billion).
PU1-LP-4a1, 4b1, 4a2, and 4b2	Fail	Constructability, operability, and cost concerns. Costs for these measures are approximately 2.5 times the costs of LP-1 and LP-2 (~$25 – 27 billion). In comparison to alignments 1 and 2 above, these alignments have more constructability and operability concerns. In addition, the costs are higher (~$25 – 27 billion)
PU1-LP-5a1, 5b1, 5a2, and 5b2	Fail	Constructability, operability, and cost concerns. Costs for these measures are approximately 2.5 times the costs of LP-1 and LP-2 (~$25 – 27 billion). In comparison to alignments 1 and 2 above, these alignments have more constructability and operability concerns. In addition, the costs are higher (~$25 – 27 billion)
PU1-LP-State	Pass	The State Master Plan presented three barrier alignments. Two of the alignments approximately correspond to PU1-LP-2a and PU1-LP-2b. Specific hydromodeling data will be available for the third State weir alignment (‘S’) across Lake Borgne.
PU1-HL-1a and 1b	Pass	Presents an alternative to the Surge Reduction Plan concept and will be carried through into the multi-criteria decision analysis process.

308 Note: Planning Unit 1 cost estimates assume the levees are 30 feet high and are built from the ground up. The cost
309 estimates for the ‘a’ alignments would go down if the new 100-year levees being in place are taken into account.
310 Costs assume geotextile levee construction (i.e. traditional construction methods).

Tier 2 – Initial Hydromodeling of Structural Measures

In addition to the initial screening evaluation, additional hydromodeling was necessary to resolve and further refine the possible structural measures in Planning Unit 1. Remaining formulation issues included:

- High level versus Lake Pontchartrain surge reduction alignments.
- Full barrier (non-overtopping) versus weir (overtopping) designs for the Lake Pontchartrain surge reduction alignments.
- Open versus closed tidal pass designs for the Lake Pontchartrain surge reduction alignments.
- Lake Borgne alignment ('S').
- Golden Triangle alignments ('a' or 'b').
- Inclusion or exclusion of Northshore, West Shore, and Oakville extension.
- Design level of risk reduction.

For this tier, barrier versus weir and open versus closed tidal gates were evaluated. During this step, a range of alignments were formulated to address the remaining formulation issues. With the inclusion of different levels of risk reduction, the naming convention for the structural measures was revised slightly from previous screening nomenclature. **Table 5** describes an example of the coding.

Table 5. Planning Unit 1 Codes used for Tier 2 and Tier 3 Screening

Code	Measure Code Description, e.g. PU1-LP-a-100-1
PU1-	Planning Unit 1
-LP-	Lake Pontchartrain surge reduction alignment
-HL-	High level alignment
-a-	Golden Triangle alignment at the confluence of the GIWW and MRGO
-b-	Alignment at the edge of the Golden Triangle and Lake Borgne
-100-	100-year design level
-400-	400-year design level
-1000-	1000-year design level
-1	All PU1 primary alternatives include the Lake Pontchartrain and Vicinity Project levees and upper Plaquemines levees. The primary alignments for 'LP' also include a barrier-weir across the mouth of Lake Pontchartrain with a tieback to high ground east of Slidell.
-2	Primary alignment plus Northshore and Westshore levees.
-3	Primary alignment plus Slidell and Westshore levees.

Full Barrier vs. Weir Options

The full barrier (non-overtopping) designs compared to the weir barrier designs for the Lake Pontchartrain Surge alignments were evaluated to determine the preferred design configuration. Based on the preliminary surge level results (see **Table 6**), the non-overtopping design increased surges along parts of the Mississippi coastline by up to 5.4 feet while the weir design increased surge by 3.2 feet for hurricanes of intensity greater than a 400-year event.

Table 6. Variation in Surge Elevation Impacts Mississippi Coast

Distance from LA State Border	Area	Average/Maximum Difference from Baseline Surge Elevations	
		Weir (feet)	Barrier (feet)
0 miles	Pearl River (Hwy 90)	+2.3 / +3.2	+ 3.6 / +5.4
18 miles	Clermont Harbor	+0.7 / +0.9	+1.1 / +2.0
26 miles	Bay Saint Louis	+0.6 / +0.9	+1.0 / +1.9
49 miles	Gulfport	+0.2 / +0.5	+0.4 / +1.2
70 miles	Biloxi	+0.2 / +0.4	+0.3 / +1.0

Measures in Planning Unit 1 that have the potential to impact the Mississippi coast are currently undergoing a systems analysis conducted in coordination with the Mississippi Coastal Improvements Program (MsCIP) team. LACPR and MsCIP plans may need to be reformulated to address any impacts.

The design height of a non-overtopping levee along this alignment would exceed 24 feet for the 100-year storm event (see **Table 7**), which means high costs and constructability issues. Further, this non-overtopping design would not equate to 100-year level of risk reduction to the Northshore of Lake Pontchartrain where water levels would be reduced by only 0.2 feet compared the existing condition.

Table 7. Design Criteria for Full Barrier vs. Weir Barrier

Plan	Full Barrier			Weir Barrier	
	Geo Textile	Soil Mix	Elev. (ft)	Over-flow	Elev. (ft)
LP-1b-100-1	$6,951	$9,476	25	$4,476	12.5
LP-1b-400-1	$18,549	$19,862	32	$12,773	12.5
LP-1b-1000-1	$22,422	$24,852	36	$16,083	12.5
LP-1b-100-2	$12,627	$20,577	25	$10,578	12.5
LP-1b-400-2	$27,102	$33,510	32	$22,444	12.5
LP-1b-1000-2	$32,225	$40,002	36	$27,323	12.5

Even without cost constraints, the engineering feasibility and environmental acceptability of building non-overtopping barriers would cause those measures to be eliminated from further consideration.

State's Lake Borgne Alignment ('S')

The State's Lake Borgne alignment was screened out for the same reason that the full barrier options were screened out. Hydromodeling results show unacceptable increases in water levels to the State of Mississippi.

Open vs. Closed Tidal Passes

A second design consideration for the Lake Pontchartrain surge reduction measure was whether to close the tidal passes at The Rigoletes and Chef Menteur passes with floodgates or whether to leave the passes open for environmental reasons. Evaluation of the hydromodel output for the open tidal passes revealed limited reduction in surge levels within Lake Pontchartrain. Therefore, it was determined that the closed tidal passes provide the best engineering solution for all storm conditions if a barrier plan is selected.

Tier 3 – Multi-Criteria Screening of Structural Measures

Based on the Tier 2 screening, the preliminary measures or variations of measures for further consideration included:

- High level versus Surge Reduction Plans.
- Golden Triangle Alignment 'a' versus Alignment 'b.'
- North Shore levee or Slidell Ring levee.
- West Shore (Laplace).

As part of the Tier 3 screening, structural measures were subjected to analysis using 100, 400, and 1000-year events. This resulted in the development of 16 variations of the High Level Plan and 18 variations of the Lake Pontchartrain Surge Reduction. These structural measures were then ranked using the multiple attributes previously described in **Table 1**.

Table 8 displays the ranking of the 34 measures and the screening attribute values used to conduct the ranking.

390 **Table 8. Planning Unit 1 Multi-Criteria Ranking of Measures**
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Measures	Screening Attributes												Total Value Score***	Rank
	Cost Effectiveness		Annual Equiv. Flood Damages		2075 Pop. Impacted 400-yr Event		Present Value Costs		Construction Period		Direct Impact-Wetlands			
	Ratio*	Value**	$ Million	Value**	People	Value**	$ Million	Value**	Years	Value**	Acres	Value**		
LP-1a-100-1	29.49	0.20	793	1.00	657,708	0.93	6,459	0.10	14	0.88	980	0.10	**3.21**	**1**
LP-1b-100-1	42.86	0.29	781	0.98	634,659	0.90	9,900	0.15	14	0.88	1,554	0.16	**3.36**	**2**
HL-1a-100-3	47.78	0.32	754	0.95	706,211	1.00	12,327	0.19	12	0.75	3,642	0.37	**3.59**	**3**
HL-1a-100-2	49.44	0.35	714	0.90	691,138	0.98	14,732	0.23	12	0.75	4,686	0.48	**3.69**	**4**
LP-1b-400-1	67.24	0.45	623	0.79	429,604	0.61	26,157	0.41	16	1.00	4,238	0.43	**3.69**	**5**
LP-1a-100-3	55.77	0.38	684	0.86	649,395	0.92	18,291	0.29	14	0.88	3,668	0.37	**3.69**	**6**
LP-1a-400-1	72.96	0.49	624	0.79	429,915	0.61	28,310	0.44	16	1.00	4,055	0.41	**3.74**	**7**
HL-1b-100-3	59.79	0.40	751	0.95	705,491	1.00	15,605	0.24	12	0.75	4,220	0.43	**3.77**	**8**
LP-1a-100-2	57.33	0.39	655	0.83	638,120	0.90	20,468	0.32	14	0.88	4,541	0.46	**3.78**	**9**
LP-1b-100-3	63.92	0.43	672	0.85	626,346	0.89	21,732	0.34	14	0.88	4,242	0.43	**3.81**	**10**
HL-1b-100-2	59.84	0.42	711	0.90	690,418	0.98	18,012	0.28	12	0.75	5,265	0.54	**3.87**	**11**
LP-1b-100-2	64.79	0.44	643	0.81	615,071	0.87	23,908	0.37	14	0.88	5,115	0.52	**3.89**	**12**
LP-1b-1000-1	87.47	0.59	614	0.77	415,159	0.59	34,813	0.54	16	1.00	5,100	0.52	**4.02**	**13**
HL-1a-400-1	106.37	0.72	734	0.93	466,706	0.66	29,570	0.46	16	1.00	2,540	0.26	**4.03**	**14**
LP-1a-1000-1	93.58	0.63	615	0.78	415,266	0.59	37,153	0.58	16	1.00	4,924	0.50	**4.08**	**15**
HL-1b-400-3	92.13	0.62	522	0.66	376,731	0.53	45,143	0.70	16	1.00	5,661	0.58	**4.10**	**16**
HL-1b-400-1	119.45	0.81	783	0.99	466,309	0.66	27,354	0.43	16	1.00	2,209	0.23	**4.11**	**17**
LP-1b-400-3	83.40	0.56	488	0.62	350,257	0.50	43,701	0.68	16	1.00	7,587	0.78	**4.13**	**18**
LP-1a-400-3	87.68	0.59	489	0.62	350,568	0.50	45,856	0.72	16	1.00	7,404	0.76	**4.18**	**19**
HL-1a-400-3	96.85	0.65	523	0.66	377,128	0.53	47,359	0.74	16	1.00	5,993	0.61	**4.20**	**20**
LP-1b-400-2	83.64	0.57	455	0.57	324,873	0.46	46,587	0.73	16	1.00	8,590	0.88	**4.20**	**21**
HL-1b-400-2	91.44	0.62	477	0.60	343,385	0.49	48,920	0.76	16	1.00	7,498	0.77	**4.24**	**22**
LP-1a-400-2	87.20	0.59	456	0.58	325,184	0.46	48,484	0.76	16	1.00	8,406	0.86	**4.24**	**23**
HL-1a-400-2	95.76	0.65	478	0.60	343,782	0.49	51,136	0.80	16	1.00	7,830	0.80	**4.33**	**24**
HL-1a-1000-1	131.12	0.89	722	0.91	436,473	0.62	38,025	0.59	16	1.00	3,211	0.33	**4.34**	**25**
HL-1b-1000-1	147.97	1.00	772	0.97	436,275	0.62	35,512	0.55	16	1.00	2,940	0.30	**4.45**	**26**
LP-1b-1000-3	100.76	0.68	471	0.59	330,322	0.47	54,510	0.85	16	1.00	9,042	0.92	**4.52**	**27**
HL-1b-1000-3	111.76	0.76	501	0.63	337,952	0.48	57,111	0.89	16	1.00	7,491	0.77	**4.52**	**28**
LP-1a-1000-3	105.28	0.71	472	0.60	330,429	0.47	56,850	0.89	16	1.00	8,865	0.91	**4.57**	**29**
LP-1b-1000-2	100.88	0.68	441	0.56	307,571	0.44	57,603	0.90	16	1.00	10,081	1.03	**4.60**	**30**

Measures	Screening Attributes												Total Value Score***	Rank
	Cost Effectiveness		Annual Equiv. Flood Damages		2075 Pop. Impacted 400-yr Event		Present Value Costs		Construction Period		Direct Impact-Wetlands			
	Ratio*	Value**	$ Million	Value**	People	Value**	$ Million	Value**	Years	Value**	Acres	Value**		
HL-1a-1000-3	116.91	0.79	502	0.63	338,150	0.48	59,625	0.93	16	1.00	7,763	0.79	**4.63**	**31**
LP-1a-1000-2	105.16	0.71	442	0.56	307,678	0.44	59,943	0.94	16	1.00	9,905	1.01	**4.65**	**32**
HL-1b-1000-2	112.17	0.76	463	0.58	310,658	0.44	61,583	0.96	16	1.00	9,516	0.97	**4.71**	**33**
HL-1a-1000-2	116.75	0.79	463	0.58	310,856	0.44	64,096	1.00	16	1.00	9,787	1.00	**4.81**	**34**

Indicates structural measure is included in the overall set of LACPR alternatives to be evaluated.

* Cost Effectiveness Ratio = Total Present Value Costs /Average Annual Equivalent Risk Reduction

** Value is the normalized value for the attribute where a value of 1.00 represents the greatest is the largest (lower is better)

***Total of Normalized Values (lower is better)

Based on the multi-criteria analysis and in consideration of the need to investigate a range of different ways to reduce the risk of hurricane storm damages the following structural measures were selected to be carried forward into the set of alternatives to be evaluated in the overall LACPR effort (listed in order of rankings):

LP-1a-100-1: Of all variations considered, this is the least expensive and has the lowest cost per average annual risk reduction (or biggest bang for the buck) and has the least direct impact on wetlands than any other plan; however, the spatial extent of risk reduction is limited to metropolitan New Orleans and vicinity. It should be noted that although the LP-1b-100-1 structural measure was ranked 2nd among all structural measures in Planning Unit 1, it costs considerably more than LP-1a-100-1 and has greater wetland impacts. Therefore, LP-1b-100-1 was eliminated from further consideration.

HL-1a-100-3: This measure ranked 3rd among the structural measures in Planning Unit 1 and is the least costly High Level Plan.

HL-1a-100-2: This measure ranked 4th among the structural measures in Planning Unit 1. This measure costs significantly less than the equivalent Surge Reduction measure (LP-1a-100-2) and was selected because of it's ranking.

LP-1b-400-1: This measure ranked 5th. In regards to risk reduction benefits, LP-1b-400-1 performs similarly to LP-1a-400-1 (ranked 7th) but costs less.

LP-1a-100-3: This measure ranked 6th among the structural measures in Planning Unit 1. It was selected to be included in the set of alternatives because it provides risk reduction to other areas besides metropolitan New Orleans (i.e., Laplace, Slidell, Oakville Extension) and has similar overall score (3.69) with the previous 2 structural measures.

LP-1a-100-2: This measure ranked 9th among the structural measures in Planning Unit 1. This measure was selected because it provides structural protection for the 100-year storm to developed areas on the Northshore as well as Laplace, Slidell and Oakville Extension. However, it is considerably more expensive than its equivalent High Level measure (HL-1a-100-2) and will take longer to construct.

LP-1b-1000-1: This measure ranked 13th among the structural measures in Planning Unit 1. This measure provides the least costly way to provide Category 5 level of risk reduction within Planning Unit 1.

HL-1b-400-3: This measure ranked 16th among the structural measures in Planning Unit 1. While more expensive than its equivalent Surge Reduction plan (LP-1b-400-3), it impacts considerably less wetlands. This measure provides 400-year level of protection to other areas besides metro New Orleans (i.e., Laplace, Slidell, Oakville Extension).

LP-1b-400-3: This measure ranked 18th among the structural measures in Planning Unit 1. This measure was selected for comparison with its equivalent Surge Reduction plan (HL-1b-400-3).

LP-1b-1000-2: This measure ranked 30th among the structural measures in Planning Unit 1. This measure provides the greatest average annual risk reduction benefits and Category 5 risk reduction to all areas (except Plaquemines).

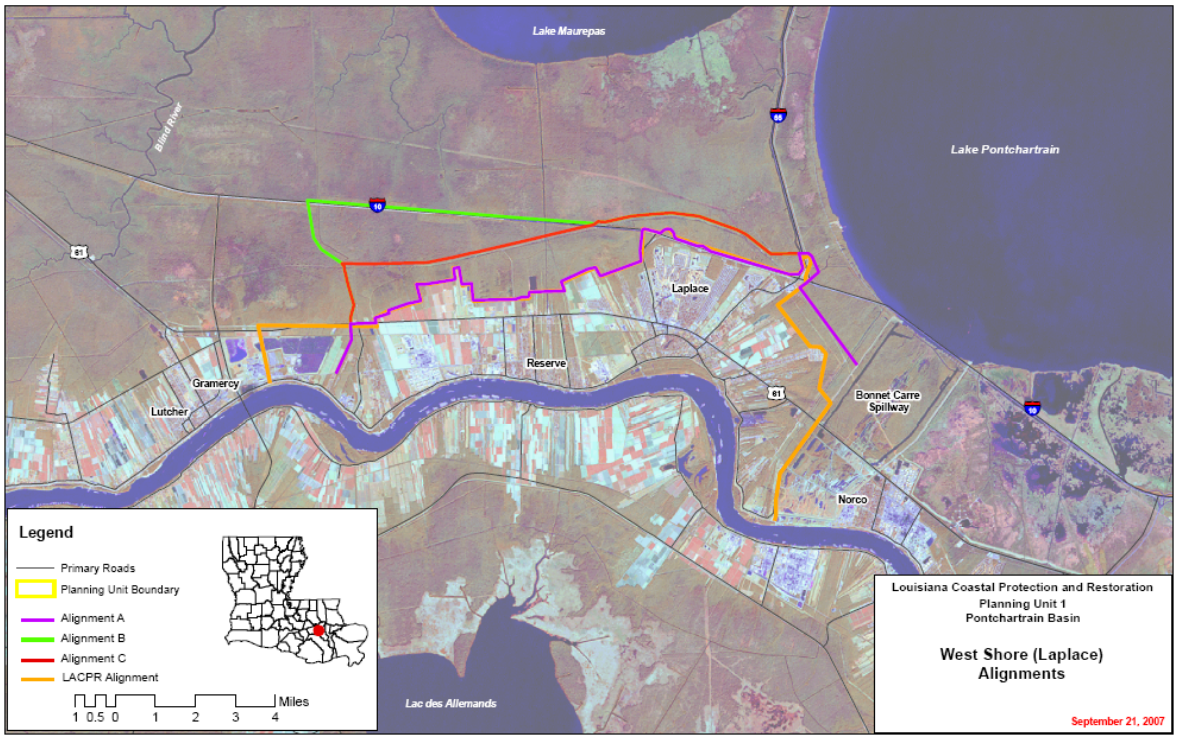
While these ten structural measures do not represent all measures in terms of reducing average annual damages, this array encompasses a sufficient range of structural risk reduction measures from which a preferred comprehensive plan or strategy can be identified.

Absent from this array of options are measures that tradeoff risk reduction of site-specific areas within Planning Unit 1. These areas can be investigated incrementally allowing for comparison of structural vs. nonstructural measures. Specifically, risk reduction of the North Shore of Lake Pontchartrain will be evaluated incrementally to address costs, risk reduction, significant engineering problems/challenges (major water courses, large pumping requirements, and lack of acceptability from locals). In addition, other areas such as Laplace and Slidell will be evaluated independently and with various levels (100, 400 and 1000-year) of risk reduction. The following sections briefly describe the North and West Shore areas.

West Shore Alignment Variations

Figure 5 presents the West Shore or Laplace alignment variations being investigated through the West Shore Lake Pontchartrain Feasibility Study. For the level of analysis in the LACPR effort, the "LACPR Alignment" acts as a representative alignment of Alignments A through C. Selection of the exact alignment would take place through the West Shore Lake Pontchartrain Feasibility Study.

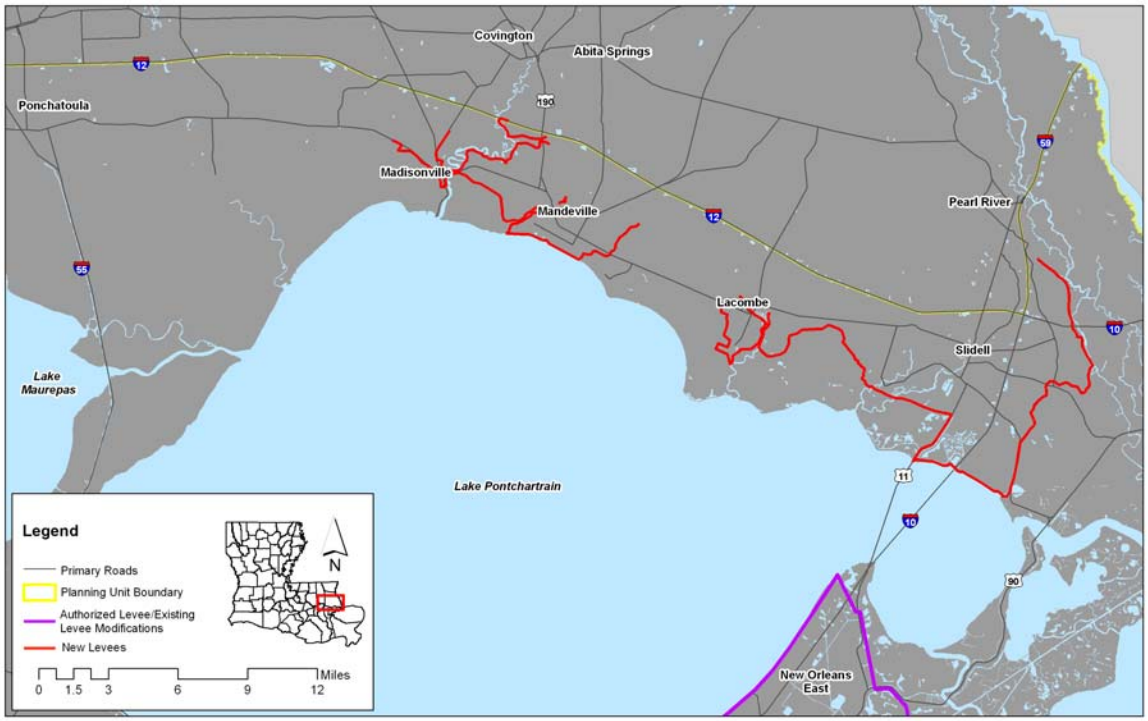
Figure 5. West Shore Alignment Options.



North Shore Alignment Refinements

Once inundation data became available, the team was able to refine the North Shore alignment from a continuous levee as shown previously in **Figure 2** to a series of ring levees as shown in **Figure 6**. These ring levees are expected to be more technically and economically viable and more publicly acceptable than a long continuous levee and will therefore be carried forward into the reevaluation in place of the continuous levee.

Figure 6. Reformulated North Shore Alignment.



In addition, the Slidell ring levee previously shown in **Figure 3** was modified slightly as shown in **Figure 7**.

Figure 7. Reformulated Slidell Ring Levee.

Other Findings

Other findings from this analysis included the following:

1) The Golden Triangle Alignment ‘b’ was generally more cost effective for the 400 and 1000-year level of risk reduction than Alignment ‘a.’

2) Providing 1000-year level of risk reduction through structural measures may appear to be a poor financial decision if considering average annual values. For the 1000-year plans, there is a 30 percent increase in cost and less than one percent increase in average annual damages prevented compared to the equivalent 400-year plans. This alone should not be reason to dismiss higher levels of risk reduction. Therefore, a structural measure that provides 1000-year level of risk reduction is kept for consideration during the multi-criteria decision analysis during which additional metrics can and will be considered.

Structural Measures to be Included in Planning Unit 1 Alternatives

Below is the array of options to be included as structural components of alternatives to be considered for detailed analysis for Planning Unit 1. These structural measures allow for comparison of further improvements to the Lake Pontchartrain and Vicinity project as well as the Northshore of Metro New Orleans (at similar levels and areas of risk reduction) for 100-year, 400-year and 1000-year levels of risk reduction. For the Planning Unit 1 alternatives, these structural components are combined with coastal restoration and nonstructural measures to provide comprehensive risk reduction.

Lake Pontchartrain Barrier Levee Alignments:

LP-1a-100-1: This structural option targets a 100-year level of risk reduction. This structural option includes building a 12.5-foot elevation weir across the mouth of Lake Pontchartrain to act as a surge barrier and extending the levee system east of Slidell up to high ground near Interstate 59. Storm gates would close the passes at Chef Menteur and The Rigoletes.

LP-1a-100-2: This structural option targets a 100-year level of risk reduction. This structural option contains the same surge barrier weir as LP-1a-100-1 but it adds levee on the Northshore, a levee around Laplace, and a levee in Plaquemines Parish on the east bank of the Mississippi River across from Oakville.

LP-1a-100-3: This structural option targets a 100-year level of risk reduction. This structural option contains the same surge barrier weir as LP-1a-100-1 but it adds a ring levee around Slidell on the Northshore, a levee around Laplace, and a levee in Plaquemines Parish on the east bank of the Mississippi River across from Oakville.

LP-1b-400-1: This structural option targets a 400-year level of risk reduction. This structural option contains the same surge barrier weir as LP-1a-100-1 but it includes raising existing levees to a 400-year level of risk reduction. This option also includes a new levee approximately between Chef Menteur Pass and Bayou Dupre that would follow Lake Borgne along the edge of the wetlands; construction would include sector gates on both the MRGO and GIWW.

LP-1b-400-3: This structural option targets a 400-year level of risk reduction. This structural option contains the same surge barrier weir as LP-1a-100-1 but it adds a ring levee around Slidell on the Northshore, a levee around Laplace, and a levee in Plaquemines Parish on the east bank of the Mississippi River across from Oakville. This option also includes a new levee approximately between Chef Menteur Pass and Bayou Dupre that would follow Lake Borgne along the edge of the wetlands; construction would include sector gates on both the MRGO and GIWW.

LP-1b-1000-1: This structural option targets a 1000-year level of risk reduction. This structural option contains the same surge barrier weir as LP-1a-100-1 but it includes raising existing levees to a 1000-year level of risk reduction. This option also includes a new levee approximately between Chef Menteur Pass and Bayou Dupre that would follow Lake Borgne along the edge of the wetlands; construction would include sector gates on both the MRGO and GIWW.

LP-1b-1000-2: This structural option targets a 1000-year level of risk reduction. This structural option contains the same surge barrier weir as LP-1a-100-1 but it adds a levee across the Northshore, a levee around Laplace, and a levee in Plaquemines Parish on the east bank of the Mississippi River across from Oakville. This option also includes a new levee approximately between Chef Menteur Pass and Bayou Dupre that would follow Lake Borgne along the edge of the wetlands; construction would include sector gates on both the MRGO and GIWW. Of all the structural measures, this measure contains the most structural components to provide a comprehensive 1000-year level of risk reduction to both the North and Southshore.

High Level Levee Alignments:

HL-1a-100-2: This structural option targets a 100-year level of risk reduction. This structural option involves building new levees but without a surge reduction barrier across Lake Pontchartrain. The new levees would include a levee on the Northshore, a levee around Laplace, and a levee in Plaquemines Parish on the east bank of the Mississippi River across from Oakville.

HL-1a-100-3: This structural option targets a 100-year level of risk reduction. This structural option involves building new levees but without a surge reduction barrier across Lake Pontchartrain. The new levees would include a ring levee around Slidell on the Northshore, a levee around Laplace, and a levee in Plaquemines Parish on the east bank of the Mississippi River across from Oakville.

HL-1b-400-3: This structural option targets a 400-year level of risk reduction. This structural option involves raising existing levees and building new levees but without a surge reduction barrier across Lake Pontchartrain. The new levees would include a ring levee around Slidell on the Northshore, a levee around Laplace, and a levee in Plaquemines Parish on the east bank of the Mississippi River across from Oakville. This option also includes a new levee approximately between Chef Menteur Pass and Bayou Dupre that would follow Lake Borgne along the edge of the wetlands; construction would include sector gates on both the MRGO and GIWW.

Planning Unit 2

The following sections provide details on the tiered screening of measures and alignments for Planning Unit 2, a triangular shaped area beginning at Donaldsonville, then extending southeast along the Mississippi River to the Gulf of Mexico. This area then continues southwest of Grand Isle and Port Fourchon and northwest along Bayou Lafourche.

Approximately 300,000 residents, or 14 percent, of the planning area population inhabits Planning Unit 2, containing the portion of the New Orleans metropolitan area located on the West Bank of the Mississippi River. Additionally, this planning unit contains Venice, Grand Isle, and portions of towns located along Bayou Lafourche such as Port Fourchon, Larose, Thibodaux, and Donaldsonville.

The major Mississippi River ports, noted in the description of Planning Unit 1 also have infrastructure on the West Bank of the Mississippi River in Planning Unit 2. Additionally, this highly productive estuary is home to a population where the social and economic cultures have evolved around and are dependent upon the estuary's natural resources.

As discussed for Planning Unit 1, the lower portion of Plaquemines Parish is a special case; therefore, screening of structural measures for this area is discussed following the screening details of Planning Unit 2.

Tier 1 – Initial Screening of Structural Measures

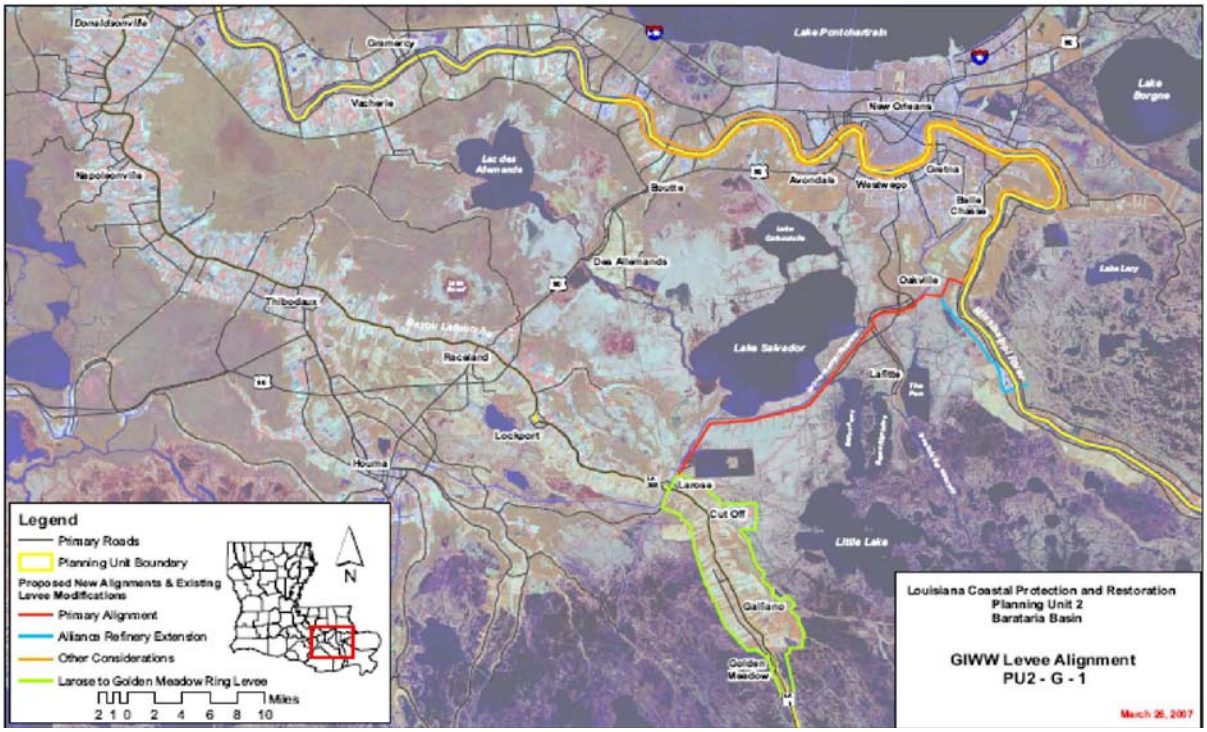
The Plan Formulation Atlas identified four primary strategies for structural risk reduction within Planning Unit 2. The alignment of the levees included the **GIWW** (three variations were

considered including structural risk reduction for Lafitte and variations of where the levee ties into to the Mississippi River Levee System), **Highway 90** alignment, **Swamp** alignment (later modified/combined with Highway 90 alignment and renamed to Ridge alignment) and two alignments along the **West Bank Interior** (improvement to existing West Bank levee and extension of the existing West Bank levee). **Table 9** describes the codes used in the Plan Formulation Atlas and for Tier 1 screening for measures in Planning Unit 2. **Figures 8** through **11** show examples of the various alignments.

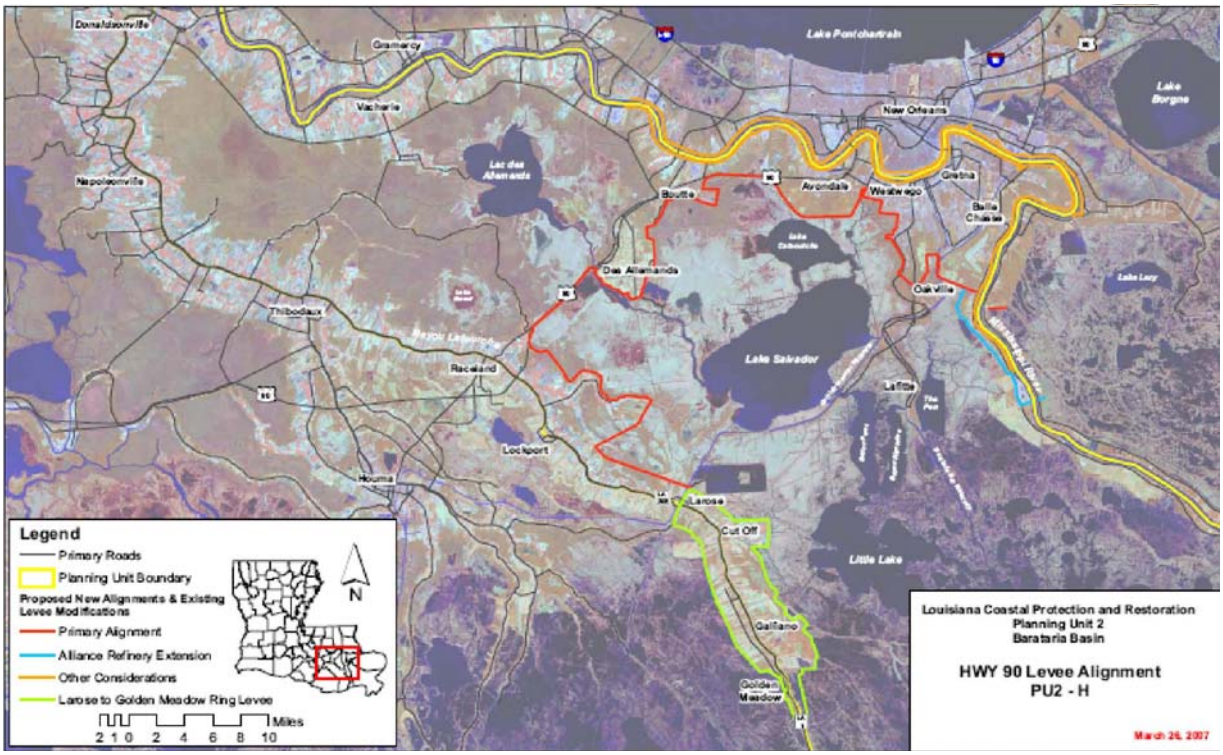
Table 9. Planning Unit 2 Codes from Plan Formulation Atlas used for Tier 1 Screening

Code	Measure Code Description (e.g. PU2-G-1)
PU2-	Planning Unit 2
-WBI-	West Bank interior alignments
-G-	GIWW levee alignment variation
-H	Highway 90 levee alignment
-S	Swamp alignment
-State	Alignment that was part of the preliminary draft State Master Plan
-#	Variations to the primary alignments (if applicable)

Figure 8. GIWW Alignment from the Plan Formulation Atlas



608 **Figure 9. Highway 90 Alignment from the Plan Formulation Atlas**
609



610
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612 **Figure 10. Swamp Alignment from the Plan Formulation Atlas**
613

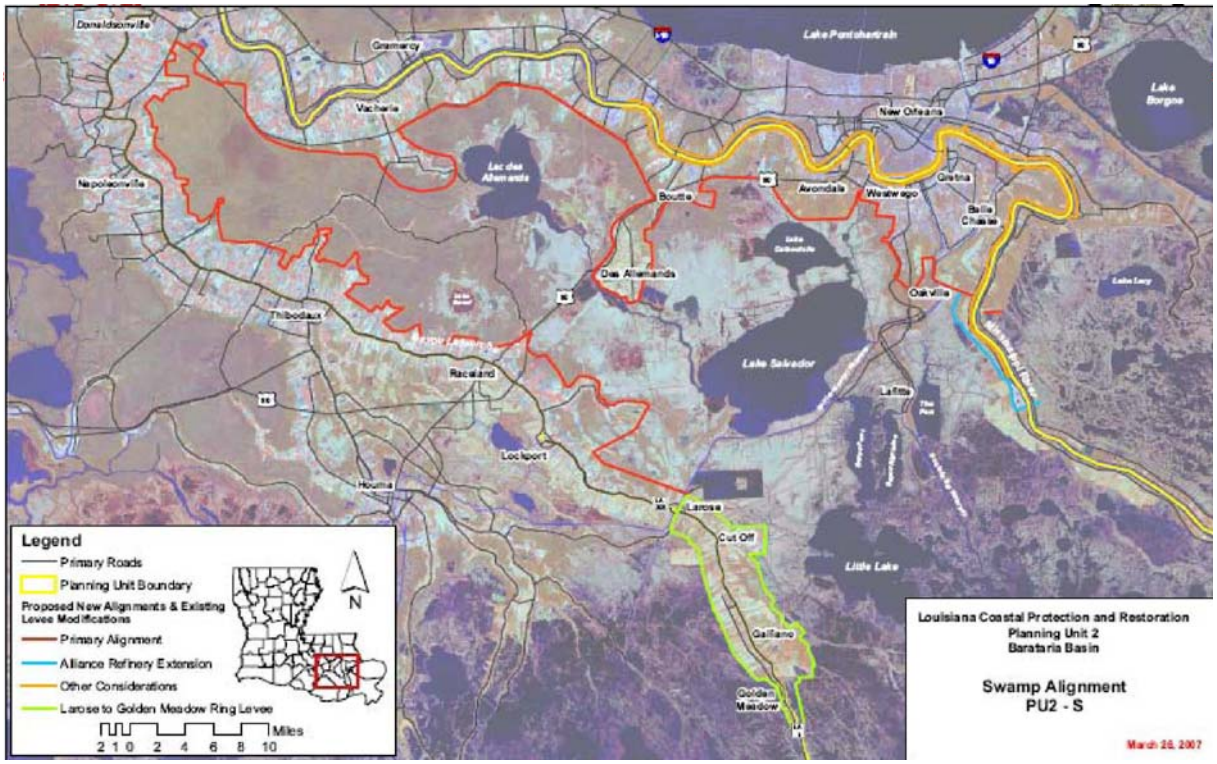

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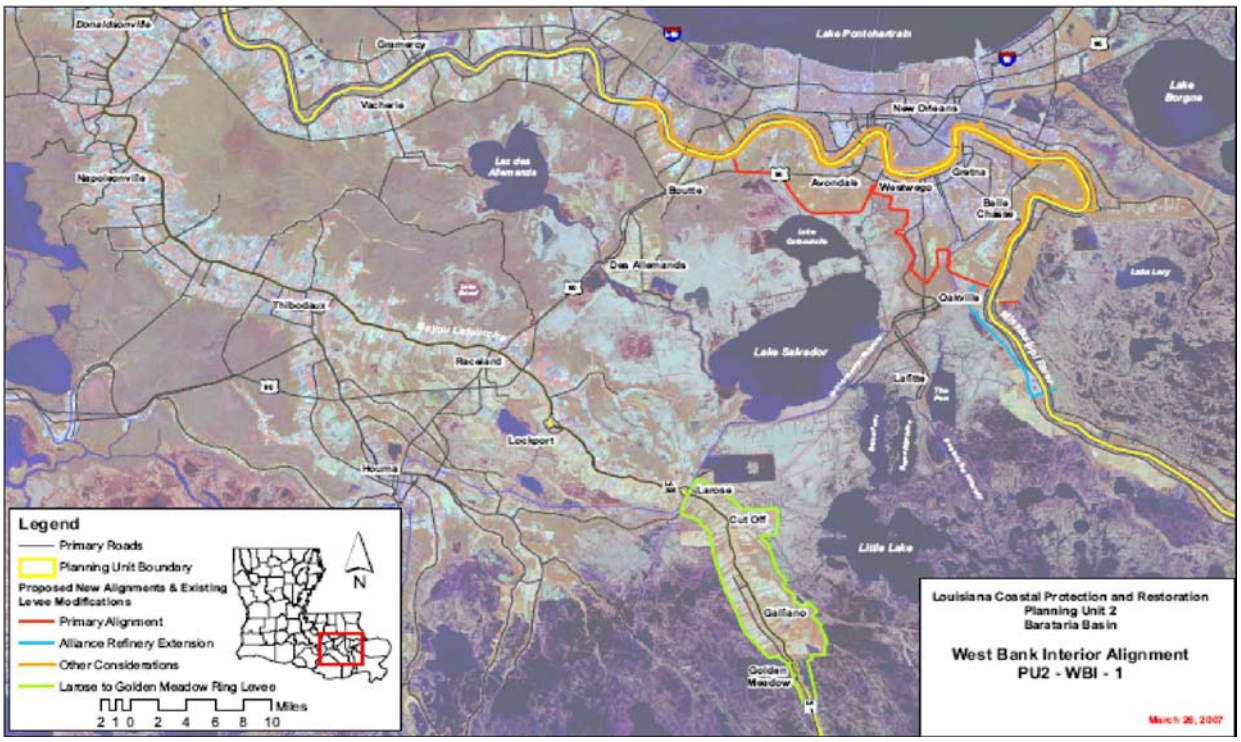
Figure 11. West Bank Interior Alignment from the Plan Formulation Atlas



Through initial screening, in which preliminary construction costs as well as direct and indirect environmental impacts were considered, the number of variations was screened to five. **Table 10** lists the variations of each of the alignments in Planning Unit 2 and describes why some alignment variations were eliminated from further consideration at this time.

Table 10. Initial Screening of Planning Unit 2 Structural Measures

Measure Code(s)	Pass/Fail	Comments
PU2-G-1	Pass	Essentially the same as the State's GIWW alignment; however, the State plan includes a ring levee around Lafitte. Cost estimates range from ~$5B - $9B depending on the height and levee construction method (i.e., 30 feet geotextile, 30 feet soil mix, or 35 feet soil mix).
PU2-G-2	Fail	Environmental concerns.
PU2-G-3	Fail	Environmental concerns.
PU2-H	Pass	Essentially the same as the State's Highway 90 alignment. For a 25-foot levee, costs range from ~$10 – 15B depending on levee construction method (geotextile versus soil mix).
PU2-S	Pass	Equivalent to the State's swamp alignment. For a 20-foot levee, costs range from ~$13 – 30B depending on the levee construction method (geotextile versus soil mix). If the swamp alignment only needs to be 20 feet up to Vacherie and Thibodaux, costs could range from $11-22B.
PU2-WBI-1	Pass	A component of the swamp alignment and also the West Bank component of the high level plan considerations in PU1.
PU2-WBI-2	Pass	A component of the swamp alignment and also the West Bank component of the high level plan considerations in PU1.
PU2-G-State	Fail	This alignment was presented in the Preliminary Draft State Master Plan but was changed to more closely resemble the GIWW alignment. Same environmental concerns as G-2 and G-3; dropped from State Master Plan.

Tier 2 – Initial Hydromodeling of Structural Measures

In addition to the initial screening evaluation, additional hydromodeling was necessary to resolve and further refine the possible structural measures. Remaining formulation issues included:

- Non-overtopping versus weir designs for the GIWW and Highway 90 alignments.
- Comparison of GIWW, Highway 90 and swamp alignments.
- Potential impacts to Plaquemines and Larose to Golden Meadow areas.
- Inclusion or exclusion of Lafitte and Des Allemands (provide structural or nonstructural risk reduction).
- Design level of risk reduction.

For this tier, non-overtopping barrier versus weir and the three alignments were evaluated (resulting in the elimination of the Highway 90 and the Swamp alignments and the creation of the Ridge alignment). During this step, a range of alignments were formulated to address the remaining formulation issues. With the inclusion of different levels of risk reduction, naming

conventions for the structural measures were revised slightly from previous screening nomenclature. **Table 11** describes the coding.

Table 11. Planning Unit 2 Codes used for Tier 2 and Tier 3 Screening

Code	Measure Code Description (e.g. PU2-WBI-100-1)
PU2-	Planning Unit 2
-WBI-	West Bank Interior Plan.
-R-	Ridge Alignment Plan
-G-	GIWW Alignment Plan
-100-	100-year design level
-400-	400-year design level
-1000-	1000-year design level
-1	All PU2 primary alignments include West Bank and Vicinity levees with new sector gate and Larose to Golden Meadow levees. Primary alignments for 'R' and 'G' also include Lafitte ring levees.
-2	Primary alignment plus Boutte levee.
-3	Primary alignment plus Boutte and Des Allemands levee.
-4	Primary alignment plus Boutte, Des Allemands, and Bayou Lafourche levees.

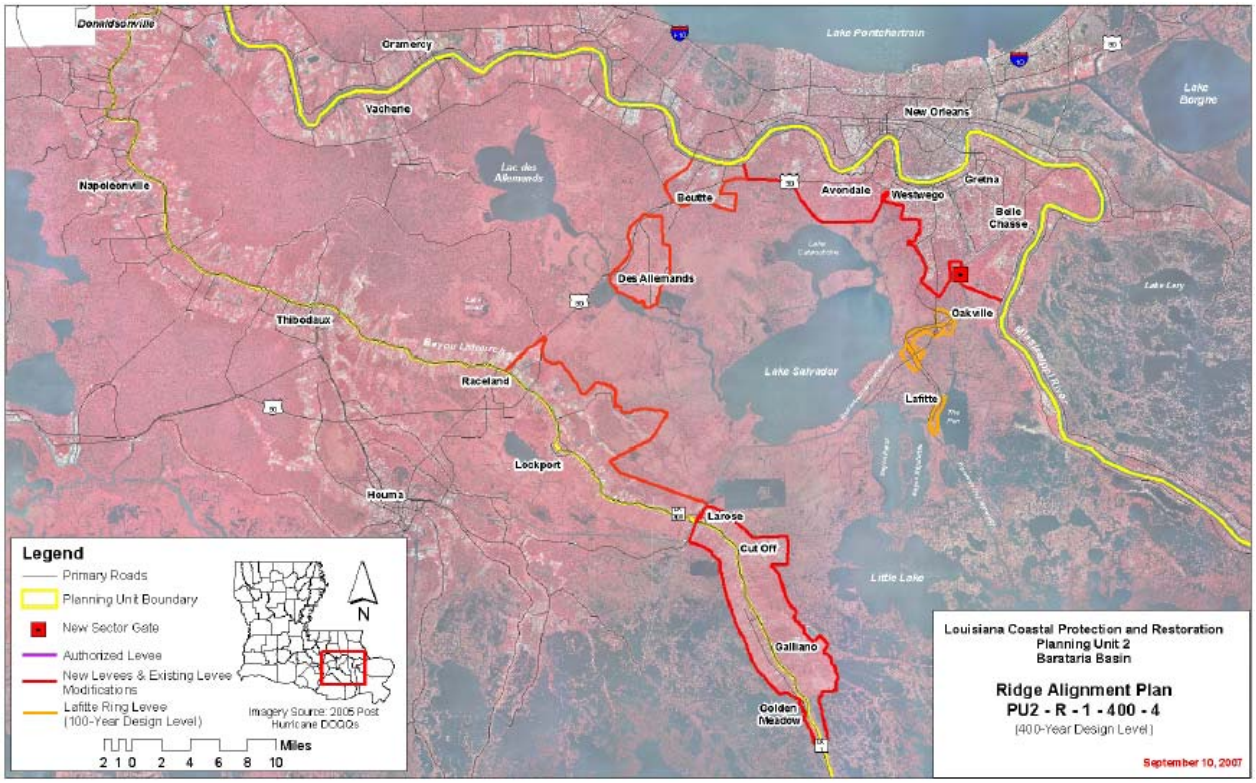
Full Barrier vs. Weir Options

The non-overtopping versus weir designs for the GIWW and Highway 90 alignments were evaluated using the surge maps produced by the hydromodels. Based on the surge level results, the weir alignments in Planning Unit 2 would be more cost effective since they perform nearly as well as their non-overtopping counterparts but would cost substantially less. In addition, the weir options have less direct and indirect wetland impacts and less constructability issues due to poor soil conditions. The weir options also minimize increases in water surface elevations along Plaquemines and Larose to Golden Meadow levees compared to the non-overtopping barriers.

Combining the Swamp and Highway 90 Alignments into the Ridge Alignment

As a result of the hydromodeling, which revealed that the estimated storm surge for the 1000-year event does not impact areas of concentrated assets beyond Highway 90, the swamp alignment and Highway 90 alignments were found to be unnecessary for risk reduction and were therefore modified to follow the natural ridges and portions of Highway 90. This reformulated alignment is referred to as the Ridge Alignment. **Figure 12** depicts an example Ridge alignment. A separate analysis was also done for structural improvements for the Lafitte area and was added as an increment to the GIWW and Ridge alignment plans.

Figure 12. Reformulated Ridge Alignment



The remaining formulation issues would be addressed in subsequent screening (Tier 3) or in the case of structural versus nonstructural risk reduction, as part of the multi-criteria decision analysis conducted after the structural measures are combined with nonstructural and restoration measures.

Tier 3 – Multi-Criteria Screening of Structural Measures

The Planning Unit 2 structural measures were then subjected to analysis using 100, 400, and 1000-year events. This resulted in the development of three variations of the West Bank Interior, six variations of the GIWW and nine variations of the Ridge Alignment. These structural measures were then ranked using the multiple attributes previously described in **Table 1**.

Table 12 displays the ranking of the 18 measures and the screening attribute values used to conduct the ranking.

684 **Table 12. Planning Unit 2 Multi-Criteria Ranking of Measures**

Measure	Screening Attributes												Total Value Score***	Rank
	Cost Effectiveness		Annual Equiv. Flood Damages		2075 Pop. Impacted 400-yr Event		Present Value Costs		Construction Period		Direct Impact-Wetlands			
	Ratio*	Value**	$ Million	Value**	# People	Value**	$ Million	Value**	Years	Value**	Acres	Value**		
G-1-100-1	13.83	0.23	510	0.70	174,599	0.43	6,281	0.18	11	0.85	969	0.10	**2.49**	**1**
WBI-1-100-1	2.79	0.05	725	1.00	398,872	0.99	750	0.02	6	0.46	0	0.00	**2.52**	**2**
G-1-100-4	21.47	0.35	435	0.60	178,505	0.44	11,509	0.33	11	0.85	2,241	0.24	**2.80**	**3**
R-1-100-2	9.31	0.15	684	0.94	403,309	1.00	2,849	0.08	11	0.85	704	0.07	**3.10**	**4**
R-1-100-3	13.89	0.23	635	0.88	403,309	1.00	4,937	0.14	11	0.85	993	0.10	**3.20**	**5**
R-1-100-4	19.78	0.32	613	0.85	403,012	1.00	7,461	0.21	11	0.85	1,635	0.17	**3.40**	**6**
WBI-1-400-1	40.16	0.65	588	0.81	168,022	0.42	15,751	0.45	12	0.92	3,688	0.39	**3.65**	**7**
R-1-400-2	41.08	0.67	540	0.74	159,309	0.40	17,966	0.51	13	1.00	4,392	0.46	**3.79**	**8**
R-1-400-3	41.43	0.67	487	0.67	150,132	0.37	20,233	0.58	13	1.00	4,687	0.50	**3.79**	**9**
R-1-400-4	44.66	0.73	462	0.64	144,021	0.36	22,906	0.66	13	1.00	5,323	0.56	**3.94**	**10**
G-1-400-1	46.68	0.76	485	0.67	142,734	0.35	22,591	0.65	12	0.92	6,161	0.65	**4.00**	**11**
WBI-1-1000-1	54.07	0.88	578	0.80	161,006	0.40	21,727	0.62	13	1.00	5,152	0.54	**4.24**	**12**
G-1-400-4	50.14	0.82	400	0.55	119,794	0.30	28,438	0.81	13	1.00	7,433	0.79	**4.26**	**13**
R-1-1000-3	53.15	0.86	476	0.66	142,402	0.35	26,518	0.76	13	1.00	6,146	0.65	**4.28**	**14**
R-1-1000-2	53.96	0.88	530	0.73	151,579	0.38	24,141	0.69	13	1.00	5,857	0.62	**4.30**	**15**
R-1-1000-4	55.99	0.91	452	0.62	135,800	0.34	29,250	0.84	13	1.00	6,787	0.72	**4.43**	**16**
G-1-1000-1	57.81	0.94	484	0.67	141,362	0.35	28,061	0.80	12	0.92	8,186	0.87	**4.55**	**17**
G-1-1000-4	61.46	1.00	399	0.55	117,457	0.29	34,927	1.00	13	1.00	9,458	1.00	**4.84**	**18**

Indicates structural measure is included in the overall set of LACPR alternatives to be evaluated.

685 * Cost Effectiveness Ratio = Total Present Value Costs /Average Annual Equivalent Risk Reduction
686 ** Value is the normalized value for the attribute where a value of 1.00 represents the greatest is the largest (lower is better)
687 ***Total of Normalized Values (lower is better)

Based on the multi-criteria screening analysis and in consideration of the need to investigate a range of different ways to reduce the risk of hurricane storm damages the following 13 structural measures were selected (listed in order of rankings):

G-1-100-1: This measure ranked 1st among the structural measures in Planning Unit 2. This measure, although not the cheapest, provides flood risk reduction to the greatest number of people among all 100-year measures.

WBI-1-100-1: This measure ranked 2nd among the structural measures in Planning Unit 2 and is the least expensive of all measures.

G-1-100-4: This measure ranked 3rd among the structural measures in Planning Unit 2. Although considerably more expensive than the previous two measures (WBI-1-100-1 and G-1-100-1), it reduces average annual flood damages to levels comparable (and in most cases more efficiently) to the 400 and 1000-year measures.

R-1-100-2: This measure ranked 4th among the structural measures in Planning Unit 2. It is the least costly ridge alignment (modified swamp and Highway 90 alignments) measures.

R-1-100-3: This measure ranked 5th among the structural measures in Planning Unit 2.

R-1-100-4: This measure ranked 6th among the structural measures in Planning Unit 2. This measure provides the greatest protection among the 100-year ridge alignment measures.

WBI-1-400-1: This measure ranked 7th among the structural measures in Planning Unit 2 and is the least costly 400-year measure.

R-1-400-2: This measure ranked 8th among the structural measures in Planning Unit 2.

R-1-400-3: This measure ranked 9th among the structural measures in Planning Unit 2…

R-1-400-4: This measure ranked 10th among the structural measures in Planning Unit 2. This measure provides the greatest risk reduction among the 100-year Ridge Alignment measures.

WBI-1-1000-1: This measure ranked 12th among the structural measures in Planning Unit 2 and is the least costly 1000-year measure.

R-1-1000-4: This measure ranked 16th among the structural measures in Planning Unit 2 and was selected for comparison purposes with the other 1000-year measures.

G-1-1000-4: This measure ranked last among the structural measures in Planning Unit 2. This structural measure provides the greatest risk reduction in terms of average annual damages prevented and the number of people impacted by flooding from a hurricane event.

Structural Measures to be Included in Planning Unit 2 Alternatives

Below are descriptions of the measures to be included as structural components of alternatives to be considered for detailed analysis for Planning Unit 2. These structural measures allow for comparison of further improvements to the existing West Bank, as well as, detailed comparison of the GIWW versus Ridge alignments (at similar levels and areas of risk reduction) for 100-year, 400-year and 1000-year levels of risk reduction. For the Planning Unit 2 alternatives, these structural components have been combined with coastal restoration and nonstructural measures to provide comprehensive risk reduction.

West Bank Interior Levee Alignments:

WBI-1-100-1: This structural option targets a 100-year level of risk reduction. The only new feature in this option involves an improvement to the existing West Bank and Vicinity project, which would be to add Sector Gate South on Bayou Barataria to keep surge from entering the existing interior canals on the West Bank of Metro New Orleans. This option assumes that the existing Larose to Golden Meadow ring levee which is authorized at a 100-yr level of risk reduction will be raised to the new 100-year design heights as part of the baseline condition.

WBI-1-400-1: This structural option is similar to WBI-1-100-1 but targets a 400-year level of risk reduction. This option also includes raising the Larose to Golden Meadow ring levee to 400-year design heights.

WBI-1-1000-1: This structural option is similar to WBI-1-100-1 but targets a 1000-year level of risk reduction. This option also includes raising the Larose to Golden Meadow ring levee to 1000-year design heights and ring levee that provides 100-year level of risk reduction for Laffite.

Ridge Levee Alignments:

R-1-100-2: This structural option targets a 100-year level of risk reduction. This structural option builds on WBI-1-100-1 but also includes extending the existing West Bank and Vicinity levee along the edge of development to include the Luling/Boutte area. Further, this option includes 100-year level of risk reduction to the Laffite through a series of four ring levees (Crown Point, Jean Laffite, Laffite, and Barataria) known collectively as the Lafitte ring levees.

R-1-100-3: This structural option targets a 100-year level of risk reduction. This structural option builds on and includes the same features as R-100-2 but also includes extending the existing Larose to Golden Meadow levees along the edge of development to include communities along Bayou Lafourche south of Highway 90 and Lafitte ring levees would be raised to the 100-year level.

R-1-100-4: This structural option targets a 100-year level of risk reduction. This structural option builds on and includes the same features as R-100-2 but also includes extending the existing Larose to Golden Meadow levees along the edge of development to include communities along Bayou Lafourche south of Highway 90. In addition, existing Des Allemands and Lafitte ring levees would be raised to the 100-year level.

R-1-400-2: This structural option targets a 400-year level of risk reduction. This structural option contains the same features at R-1-100-2 but all levees would be raised or built to the 400-year level with the exception of the Lafitte ring levees which would be raised to the 100-year level.

R-1-400-3: This structural option targets a 400-year level of risk reduction. This structural option contains the same features at R-1-100-3 but all levees would be raised or built to the 400-year level with the exception of the Lafitte ring levees which would be raised to the 100-year level.

R-1-400-4: This structural option targets a 400-year level of risk reduction. This structural option includes the same features as R-1-100-4 but involves building those levees at a 400-year design height (except the Lafitte ring levees which would be at the 100-year design) as well as raising existing levees on the West Bank of New Orleans and the existing Larose to Golden Meadow ring levee to a 400-year design height.

R-1-1000-4: This structural option targets a 1000-year level of risk reduction. This structural option includes the same features as R-1-100-4 and R-1-400-4 but involves building those levees at a 1000-year design height (except the Lafitte ring levee which would be at the 100-year design) as well as raising existing levees on the West Bank of New Orleans and the existing Larose to Golden Meadow ring levee to a 1000-year design height.

GIWW Levee Alignments:

G-1-100-1: This structural option targets a 100-year level of risk reduction. This option builds on and includes the same features as WBI-1-100-1 and also consists of a surge reduction barrier in the form of a 12.5-foot elevation weir that roughly follows the GIWW, which already acts as a partial barrier. Structures would consist of sixteen 50-foot tainter gates, a 110-foot sector gate on Bayou Perot, and a 110-foot lock on Bayou Barataria and ring levees that provides 100-year level of risk reduction for Laffite

G-1-100-4: This structural option targets a 100-year level of risk reduction. The option includes the same new levee alignments as described in R-1-100-4 but also includes the 12.5-foot elevation surge reduction barrier weir that is described in G-1-100-1.

G-1000-4: This structural option targets a 1000-year level of risk reduction. The option includes the same weir and levees described in G-1-100-4 but levees would be at the 1000-year design height.

Special Case: Lower Plaquemines Parish

Plaquemines Parish, which is split roughly in half by the Mississippi River, lies in both Planning Units 1 and 2. The portion of Plaquemines Parish on the east side of the Mississippi River is contained in Planning Unit 1 and the west side is contained in Planning Unit 2. Because of its unique nature, the portions of Plaquemines Parish below Belle Chasse are handled as a special case for plan formulation.

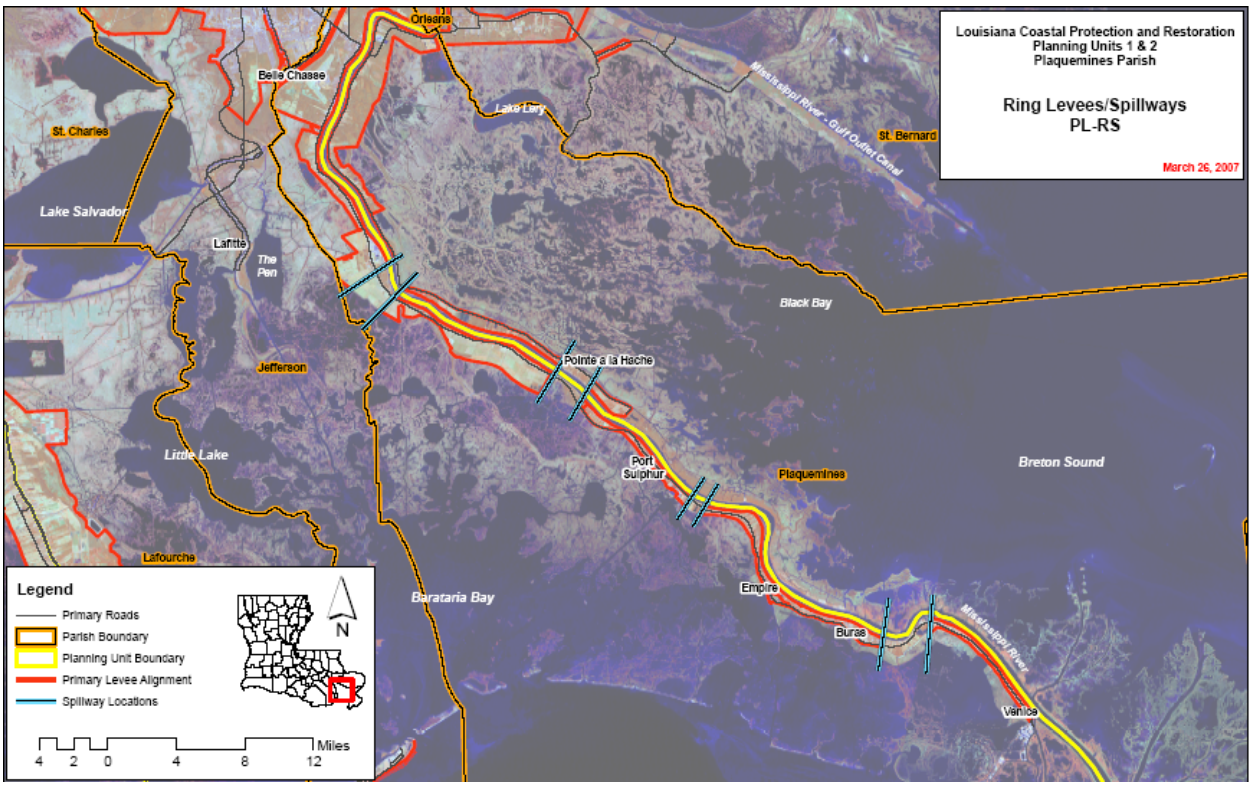
Tier 1 – Initial Screening of Structural Measures

The Plan Formulation Atlas presented four options for increased risk reduction in Plaquemines Parish:

1. **Ring Levees/Spillways (PL-RS)** – This option proposes spillways in combination with ring levees in multiple locations in Plaquemines Parish. The spillway concept was envisioned to reduce hurricane surge in the New Orleans area and Plaquemines Parish by degrading sections of the existing Plaquemines Parish levees to allow storm surge transfer between Breton Sound and Barataria Bay areas. Highway bridges would be constructed over degraded levee reaches.
2. **Closed Ring Levee System (PL-RL)** – This option includes a series of basins (ring levees) that would provide an increased level of risk reduction to critical facilities and more densely populated areas of lower Plaquemines Parish. Levee sections outside the closed ring levee areas would remain at existing height.
3. **Federal Levee Alignment (PL-FL)** – This option proposes to raise the height of all Federal levees in lower Plaquemines Parish to the 100-year design level and to leave the non-Federal levees at existing height.
4. **Existing Levee Alignment (PL-EL)** – This option would incorporate non-Federal levees in Plaquemines Parish into the Federal levee system and raise the height of all existing levees in lower Plaquemines Parish.

Figure 13 displays the ring levee/spillway concept in Plaquemines Parish. Note: The location and width of spillways is purely conceptual. For the hydromodeling evaluation used in the Tier 2 screening only three spillways were considered.

Figure 13. Plaquemines Ring Levee/Spillway Concept from the Plan Formulation Atlas



Following hurricanes Katrina and Rita, the USACE conducted a study to provide risk reduction though structural measures in lower Plaquemines Parish. Specifically, two options that provide 100-year level of risk reduction were developed for that study. These options include:

1. Creation of ring levees around the most populated portions of the Parish (estimated cost of roughly $3.6 billion) and
2. Providing 100-year risk reduction to the entire lower Plaquemines Parish by raising and armoring existing levees (estimated cost of roughly $5.8 billion).

As a result of the high cost and the potential surge increase in Louisiana and Mississippi created by levees in this area, both the State Master Plan stakeholder process and the USACE screening process eliminated most of the structural measures in lower Plaquemines Parish. **Table 13** summarizes the results of the Tier 1 screening.

Table 13. Screening Results for Lower Plaquemines Parish

Measure Code(s)	Pass/Fail	Comments
PL-RS	Pass	Spillway concept carried forward pending hydromodeling results to evaluate regional benefits.
PL-RL	Fail	Excessively high costs; constructability issues; lack of stakeholder support; transportation access issues (would require elevated roadways connecting areas inside and outside the ring levees).
PL-FL	Fail	Excessively high costs; constructability issues; lack of stakeholder support.
PL-EL	Fail	Excessively high costs; constructability issues; lack of stakeholder support.

Tier 2 – Initial Hydromodeling of Structural Measures

In order to understand the influence of the Mississippi River levees and adjacent back levees in lower Plaquemines Parish, the following two cases were modeled:

1. The creation of three spillways (totaling 9.5 miles) across the lower Mississippi River;
2. The removal of all levees (totaling 57 miles) along the Mississippi River within the delta which allows the relatively free flow of water across the Mississippi River.

This analysis was designed to understand how surge builds up along these levees from Breton Sound and propagates towards New Orleans and Baton Rouge in the Mississippi River. In addition, the effectiveness of building localized ring levees to provide a higher level of risk reduction in lower Plaquemines Parish can be ascertained.

The first case described above for the spillway concept did not produce significant regional reductions in water levels. The second case (tearing down all levees) did produce some reductions in regional water levels; however, this approach would not likely be acceptable. In general, the results are inconclusive for making a recommendation at this time. The spillway concept appears to have some merit but further study is needed.

Planning Unit 3a

The following sections provide details on the tiered screening of structural measures and alignments for Planning Unit 3a. Planning Unit 3a begins in Baton Rouge and continues south along the Mississippi River and Bayou Lafourche to the Gulf of Mexico. The boundary then extends westward to Bayou de West, and then generally follows Bayou de West north to Interstate Highway 10 and back to Baton Rouge. The Planning Unit consists of Terrebonne, St. Mary (East Bank), Lafourche (West Bank), Assumption (West Bank), and St. Martin (East Bank) Parishes.

This planning unit includes approximately 249,000, or 12 percent, of the population within the overall planning area. Communities at risk in this Planning Unit include a portion of the Baton Rouge metropolitan area as well Bayou Cane, Houma, Morgan City, Raceland and Thibodaux among others.

This planning unit contains infrastructure assets in and around population centers, consisting of oil and gas infrastructure, marinas, and port facilities.

Tier 1 – Initial Screening of Structural Measures

The Plan Formulation Atlas identified three primary strategies for structural risk reduction in Planning Unit 3a. They include a **GIWW** alignment (**Figure 14**), a **Morganza to the Gulf** alignment (**Figure 15**) and an **Atchafalaya Backwater** alignment (**Figure 16**). The alignments proposed in PU3a would provide flood risk reduction to Lockport, Raceland, Houma, Thibodaux and Morgan City, among others. The GIWW alignment would consist of a new levee along the GIWW from Larose to Morgan City or to Thibodaux with a ring levee around Morgan City. The Morganza to the Gulf alignment proposes to add a levee using the Morganza to the Gulf alignment from Larose to Morgan City or Thibodaux with a ring levee around Morgan City. The Atchafalaya Backwater alignment would consist of a new levee around the backwaters of the Atchafalaya including ring levees and the recently authorized Morganza to the Gulf levee alignment. Within these three strategies, the Plan Formulation Atlas identified six variations including an alignment identified in the State Master Plan. **Table 14** describes the codes used in the Plan Formulation Atlas and for Tier 1 screening for measures in Planning Unit 3a.

Table 14. Planning Unit 3a Codes from Plan Formulation Atlas used for Tier 1 Screening

Code	Measure Code Description (e.g. PU3a-G-1)
PU3a-	Planning Unit 3a
-M-	Morganza levee alignment
-G-	GIWW levee alignment with Morganza Levee at 100-year design
-AB	Atchafalaya backwater alignment
-State	Alignment that was part of the preliminary draft State Master Plan
-#	Variations to the primary alignments (if applicable)

Figures 14 through **16** show examples of the various structural measure alignments.

Figure 14. Example GIWW Alignment from the Plan Formulation Atlas

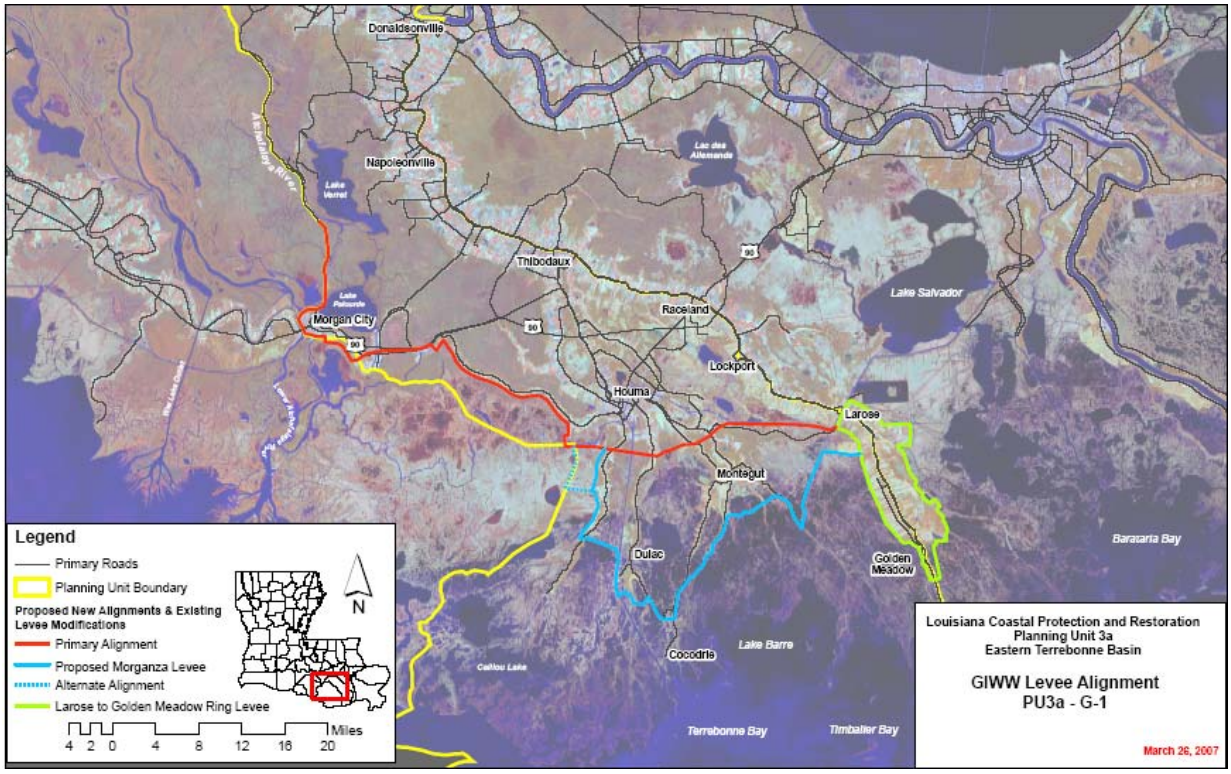


Figure 15. Example Morganza to the Gulf Alignment from the Plan Formulation Atlas

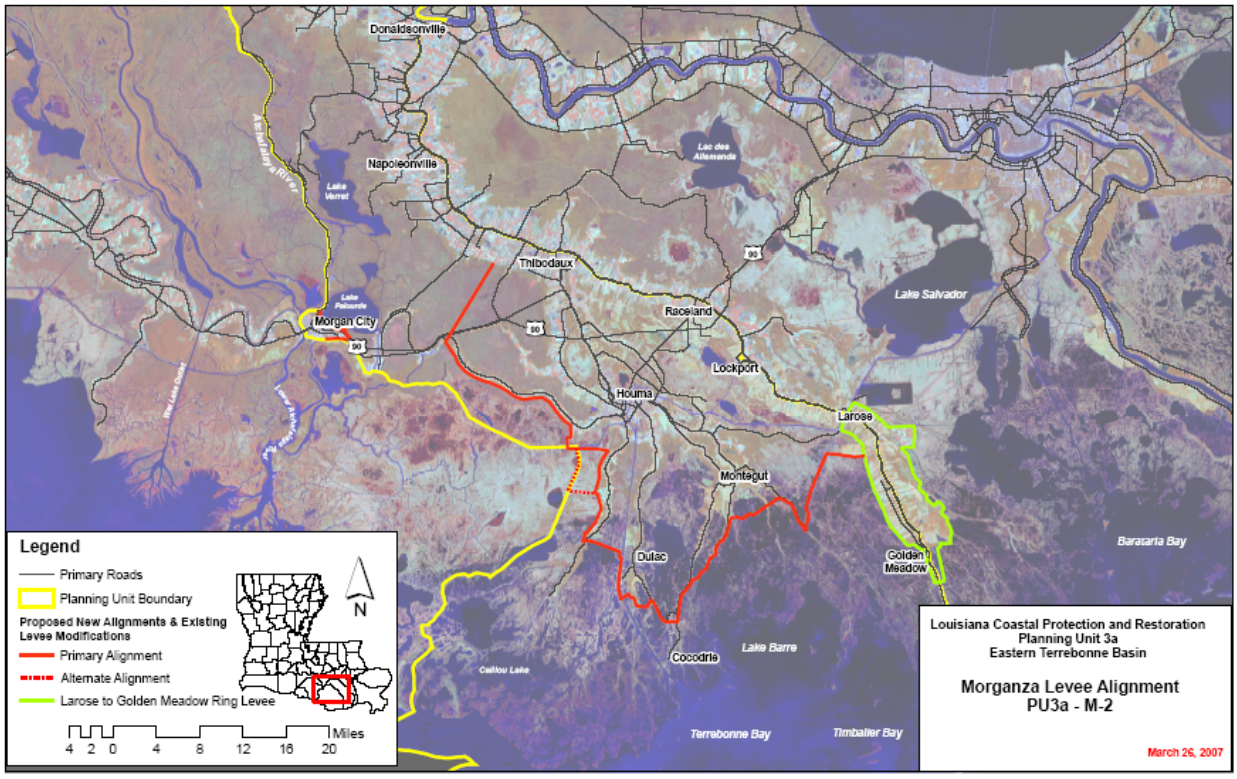
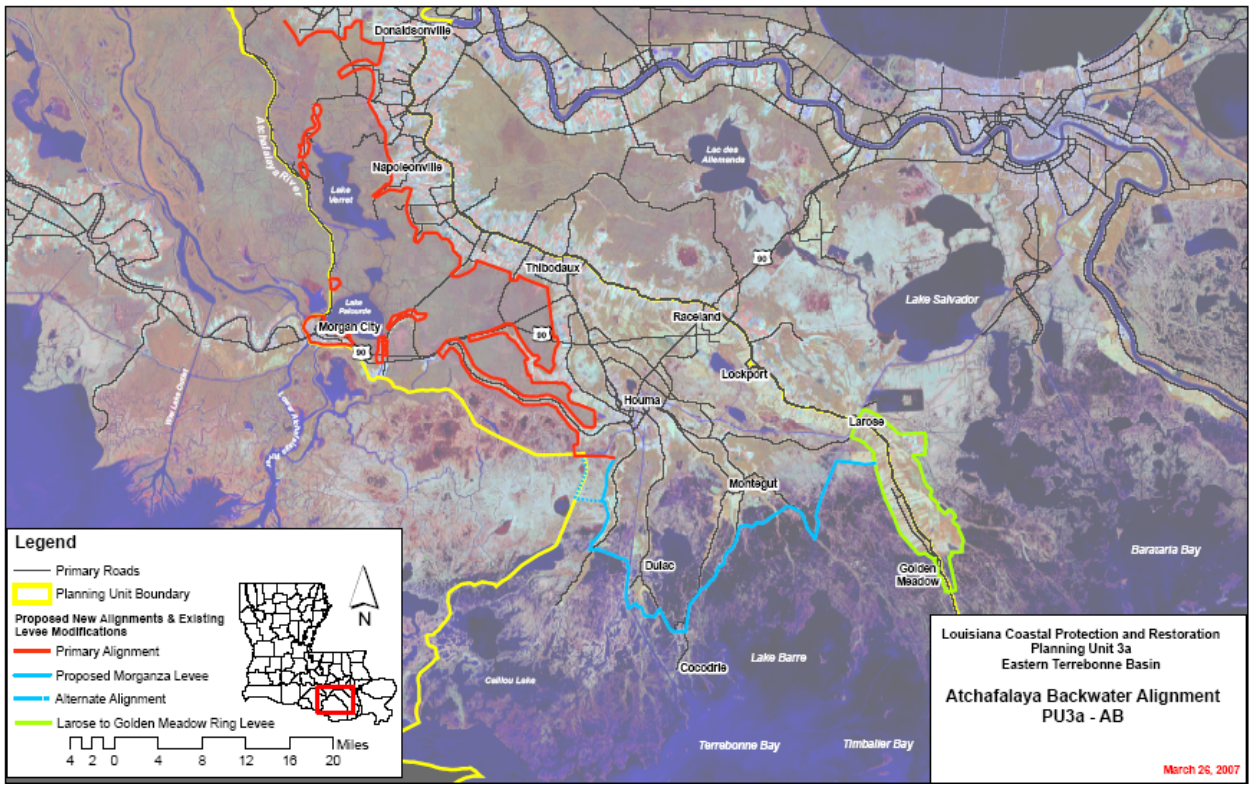


Figure 16. Atchafalaya Backwater Alignment from the Plan Formulation Atlas



Through the first tier of screening, in which preliminary construction costs, constructability as well as direct environmental impacts were considered, the number of variations was screened to three. **Table 15** lists the variations of the levee alignments and describes why some alignment variations were eliminated from further consideration at this time.

Table 15. Initial Screening of Planning Unit 3a Structural Measures

Measure Code(s)	Pass/Fail	Comments
PU3a-G-1	Pass	Similar to GIWW alignment in SMP; works well with bypass channel identified in the coastal restoration measures. The levee may only have to be built to 10 or 15 feet.
PU3a-G-2	Pass	Related to Morganza to the Gulf tie back associated with new 100-year surge data. This option may be incomplete because it would require parts of PU3a-AB to be implemented.
PU3a-M-1	Fail	Excessive costs; doesn't prevent flooding from hurricane surge and wave run-up.
PU3a-M-2	Fail	Excessive costs; doesn't prevent flooding from hurricane surge and wave run-up.
PU3a-AB	Fail	Excessive costs
PU3a-State	Pass	Similar to G-1 but includes additional alignment from Golden Meadow to Pointe au Chene that will likely be screened out due to environmental concerns and poor soil conditions (higher cost/mile). Bayou DuLarge levee alignment creates a surge amplification.

Tier 2 – Initial Hydromodeling of Structural Measures

In addition to the initial screening evaluation, additional hydromodeling was necessary to resolve and further refine the possible structural measures in Planning Unit 3a. Remaining formulation issues included:

- Comparison of the various GIWW alignments.
- A continuous levee or a ring levee for Morgan City.
- Design level of risk reduction.

The hydromodeling revealed that the measures from the Plan Formulation Atlas needed to be reformulated based on areas impacted and the location of concentrated assets. This resulted in three structural measures including:

- A continuous levee from Larose in the east to Morgan City in the west then north where it will tie into the ridge following the Bayou Black. This alignment is similar to the recently authorized Morganza levee (**Figure 17).**
- Modification to the Morganza Alignment by tying back the Morganza levee to high ground south of Thibodaux. This measure includes a ring levee around Morgan City (**Figure 18**).
- This measure is the same as described in the previous bullet but it includes a levee along the GIWW to create a secondary line of defense (**Figure 19**).

960 **Figure 17. Reformulated Morganza Levee Alignment with Tie-in West of Morgan City**
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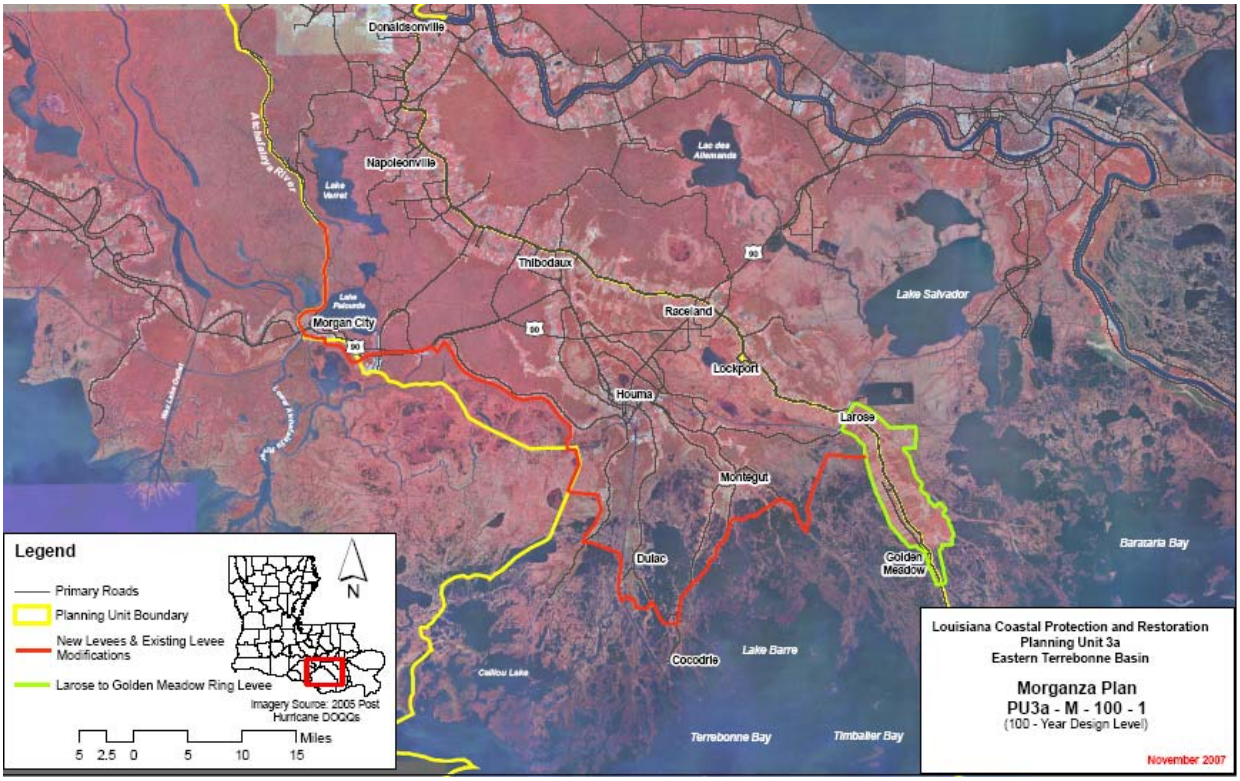

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964 **Figure 18. Reformulated Morganza Levee Alignment with Morgan City Ring Levee**
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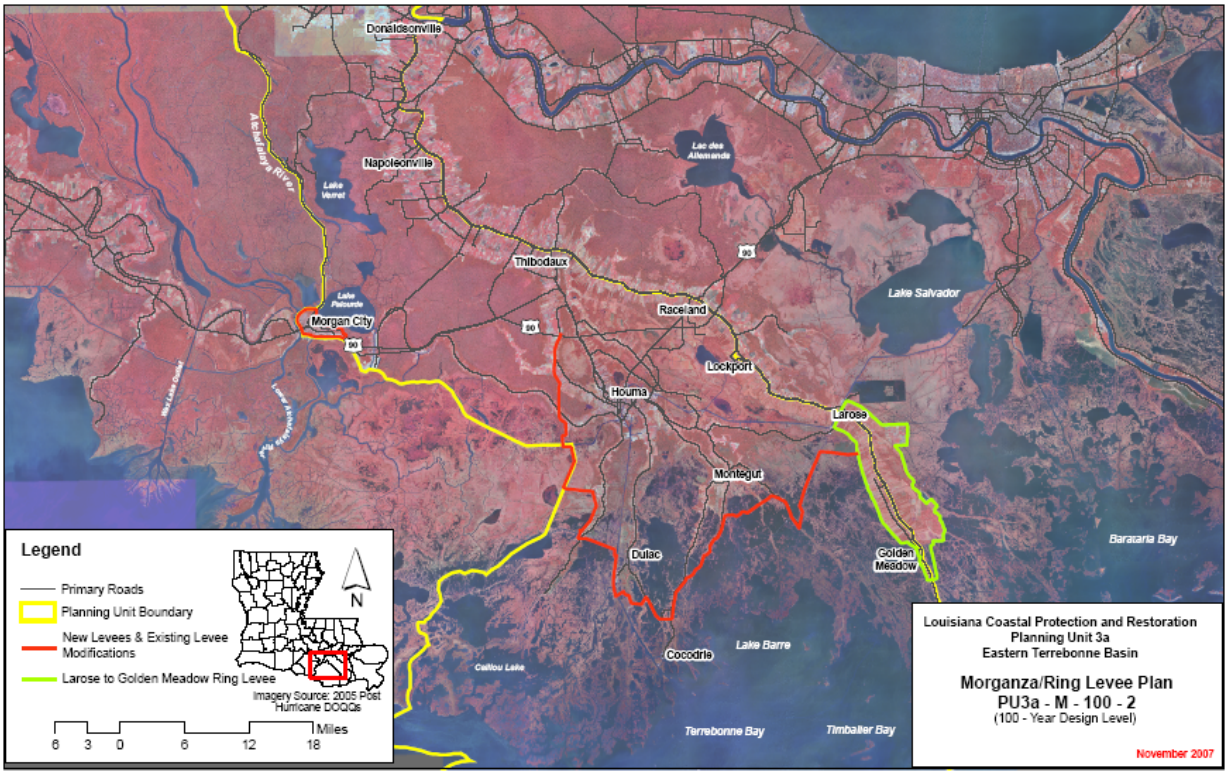

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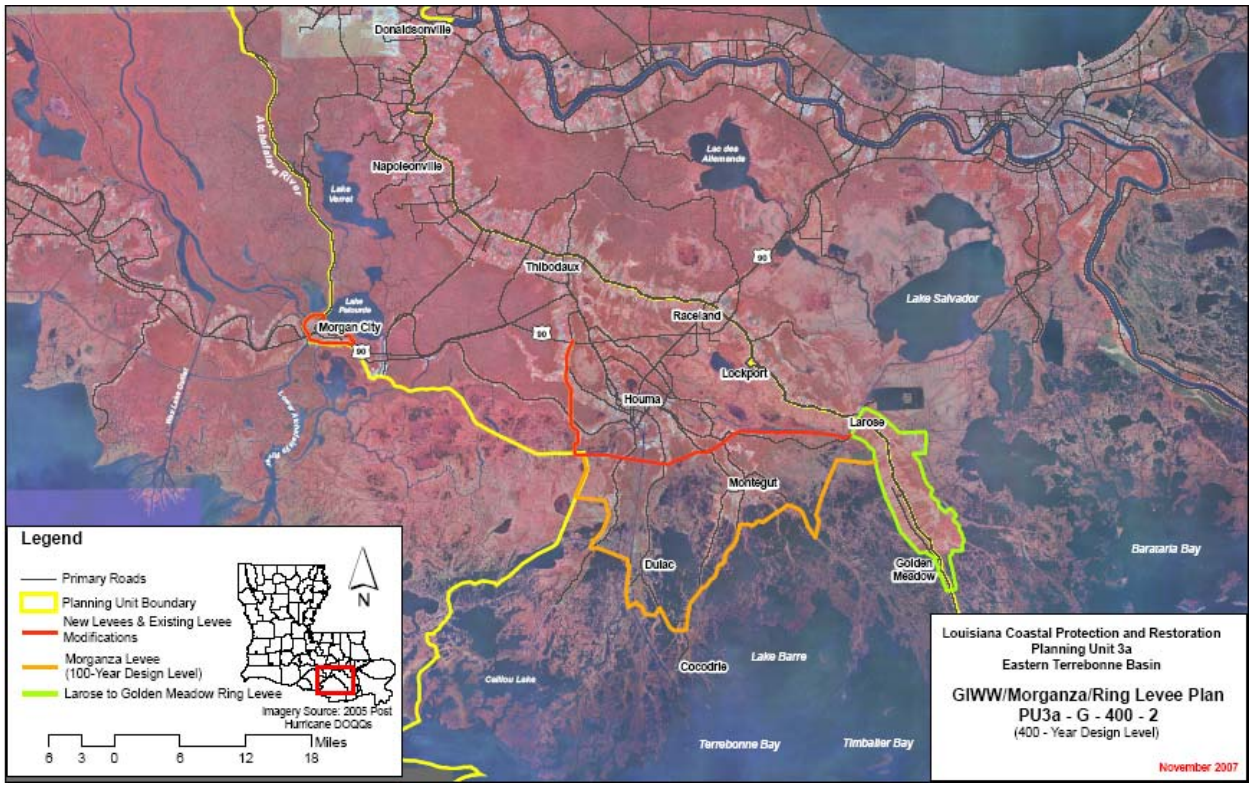
Figure 19. Reformulated GIWW Alignment



With the inclusion of different levels of risk reduction, name convention for the structural managements measures were revised slightly from previous screening nomenclature. **Table 16** describes the coding.

Table 16. Planning Unit 3a Codes used for Tier 2 and Tier 3 Screening

Code	Measure Code Description (e.g. PU3a-M-100-1)
PU3a-	Planning Unit 3a
-M-	Morganza Levee alignment
-G-	GIWW Alignment Plan with Morganza Levee at 100-year design
-100-	100-year design level
-400-	400-year design level
-1000-	1000-year design level
-1	Morganza alignment with tieback to high ground west of Morgan City
-2	Morganza alignment with tieback to high ground south of Thibodaux and ring levee around Morgan City

Tier 3 – Multi-Criteria Screening of Structural Measures

The Planning Unit 3a structural measures were then subjected to analysis using 100, 400, and 1000-year events. This resulted in the development of six variations of the Morganza Levee alignment and two variations of the GIWW alignments. These structural measures were then ranked using the multiple attributes previously described in **Table 1**.

Table 17 displays the ranking of the eight measures and the screening attribute values used to conduct the ranking.

988 **Table 17. Planning Unit 3a Multi-Criteria Ranking of Measures**

Measure	Screening Attributes												Total Value Score***	Rank
	Cost Effectiveness		Annual Equiv. Flood Damages		2075 Pop. Impacted 400-yr Event		Present Value Costs		Construction Period		Direct Impact-Wetlands			
	Ratio*	Value**	$ Million	Value**	# People	Value**	$ Million	Value**	Years	Value**	Acres	Value**		
PU3a-G-400-2	15.50	0.36	1,184	0.84	51,913	0.43	20,207	0.44	10	0.71	5,261	0.62	**3.41**	**1**
PU3a-G-1000-2	16.67	0.39	1,169	0.83	50,809	0.42	21,978	0.48	10	0.71	6,642	0.79	**3.62**	**2**
PU3a-M-100-1	13.82	0.32	1,207	0.86	100,745	0.83	17,701	0.38	10	0.71	4,880	0.58	**3.69**	**3**
PU3a-M-100-2	12.08	0.28	1,212	0.86	121,307	1.00	15,405	0.33	10	0.71	4,201	0.5	**3.69**	**4**
PU3a-M-400-2	23.53	0.55	1,285	0.91	34,879	0.29	28,290	0.61	12	0.86	6,128	0.73	**3.95**	**5**
PU3a-M-400-1	27.45	0.64	1,290	0.92	27,229	0.22	32,870	0.71	12	0.86	7,639	0.91	**4.26**	**6**
PU3a-M-1000-2	35.98	0.84	1,401	1.00	33,590	0.28	39,070	0.85	14	1.00	6,313	0.75	**4.71**	**7**
PU3a-M-1000-1	42.61	1.00	1,406	1.00	26,429	0.22	46,087	1.00	14	1.00	8,425	1.00	**5.22**	**8**

Indicates structural measure is included in the overall set of LACPR alternatives to be evaluated.

989 * Cost Effectiveness Ratio = Total Present Value Costs /Average Annual Equivalent Risk Reduction
990 ** Value is the normalized value for the attribute where a value of 1.00 represents the greatest is the largest (lower is better)
991 ***Total of Normalized Values (lower is better)

Based on the multi-criteria screening analysis and in consideration of the need to investigate a range of different ways to reduce the risk of hurricane storm damages the following four structural measures were selected for the final array (listed in order of rankings):

PU3a-G-400-2: This measure ranked 1st among the structural measures in Planning Unit 3a. It is the least costly among the measures designed to provide protection against the 4000-year hurricane event.

PU3a-G-1000-2: This measure ranked 2nd among the structural measures in Planning Unit 3a. It is the least costly among the measures designed to provide protection against the 1000-year hurricane event.

PU3a-M-100-1: This measure ranked 3rd among the structural measures in Planning Unit 3a. This measure is the 2nd cheapest among PU3 structural measures but impacts twice as many people than any of the 3 previous measures.

PU3a-M-100-2: This measure ranked 4th among the structural measures in Planning Unit 3a. This measure is the most cost effective among PU3a structural measures and is the least costly, however, it provides hurricane surge protection to the fewest people. The remaining structural measures in PU3a, ranked 5th – 8th, were eliminated do to the extremely high costs.

Structural Measures to be included in Planning Unit 3a Alternatives

Below is the array of options to be included as structural components of alternatives to be considered for detailed analysis for Planning Unit 3a. These structural measures allow for comparison of risk reduction improvements to Houma, Morgan City and other communities in Planning Unit 3a for 100-year, 400-year and 1000-year levels of risk reduction. For the Planning Unit 3a alternatives, these structural components are combined with coastal restoration and nonstructural measures to provide comprehensive risk reduction.

Morganza to the Gulf Levee Alignments:

PU3a-M-100-1: This structural option targets a 100-year level of risk reduction. This option involves constructing the Morganza to the Gulf levee with extension tying into high ground west of Morgan City at 100-year design level.

PU3a-M-100-2: This structural option targets a 100-year level of risk reduction. This option involves construct a portion of the Morganza to the Gulf levee from Larose west to a tieback to high ground south of Thibodaux. Included in this option is a ring levee around Morgan City at 100-year design level.

GIWW Levee Alignments:

PU3a-G-400-2: This structural option targets a 400-year level of risk reduction. This option involves construct a portion of the Morganza to the Gulf levee from Larose west to a tieback to high ground south of Thibodaux at 100-year design level. A secondary levee would be

constructed along the GIWW that provides 400-year level of risk reduction. Included in this option is a ring levee around Morgan City that provides 400-year level of risk reduction.

PU3a-G-1000-2: This structural option targets a 1000-year level of risk reduction. This option involves construct a portion of the Morganza to the Gulf levee from Larose west to a tieback to high ground south of Thibodaux at 100-year design level. A secondary levee would be constructed along the GIWW that provides 1000-year level of risk reduction. Included in this option is a ring levee around Morgan City that provides 1000-year level of risk reduction.

Planning Unit 3b

The following sections provide details on the tiered screening of measures and alignments for Planning Unit 3b. The planning unit extends from Bayou de West westward to Freshwater Bayou with Interstate Highway 10 forming the northern boundary and the southern boundary formed by the Gulf. The western boundary falls just to the west of the coastal wetlands, Abbeville and Lafayette, covering all or part of Terrebonne, St. Mary, Iberia, and Vermilion Parishes.

This planning unit includes a population of about 350,000, which represents approximately 16 percent of the population within the planning area. It includes the cities and towns of Berwick, Patterson, Franklin, Jeanerette, New Iberia, Abbeville, Garden City, Sorrel, Louisa, Avery Island, Delcambre, Erath, Henry, Intracoastal City, and others, as well as the southern portion of Lafayette. Most of the area population is located along Bayou Teche.

This planning unit contains infrastructure assets in and around population centers, consisting of oil and gas infrastructure, marinas, and port facilities.

Tier 1 – Initial Screening of Structural Measures

The Plan Formulation Atlas presented two primary strategies for structural risk reduction in Planning Unit 3b. They include an alignment along the GIWW and the Franklin to Abbeville alignment which is inland from the GIWW. Within these two strategies, the Plan Formulation Atlas presented four variations. **Table 18** describes the codes used for Tier 1 screening of measures in Planning Unit 3b. **Figure 20** and **Figure 21** show examples of the various alignments.

Table 18. Planning Unit 3b Codes from Plan Formulation Atlas used for Tier 1 Screening

Code	Measure Code Description (e.g. PU3b-G-1)
PU3b-	Planning Unit 3b
-G-	GIWW levee alignment
-FA-	Franklin to Abbeville alignment (inland of the GIWW)
-State	Alignment that was part of the preliminary draft State Master Plan
-#	Variations to the primary alignments (if applicable)

1072 **Figure 20. Example GIWW Alignment from the Plan Formulation Atlas**
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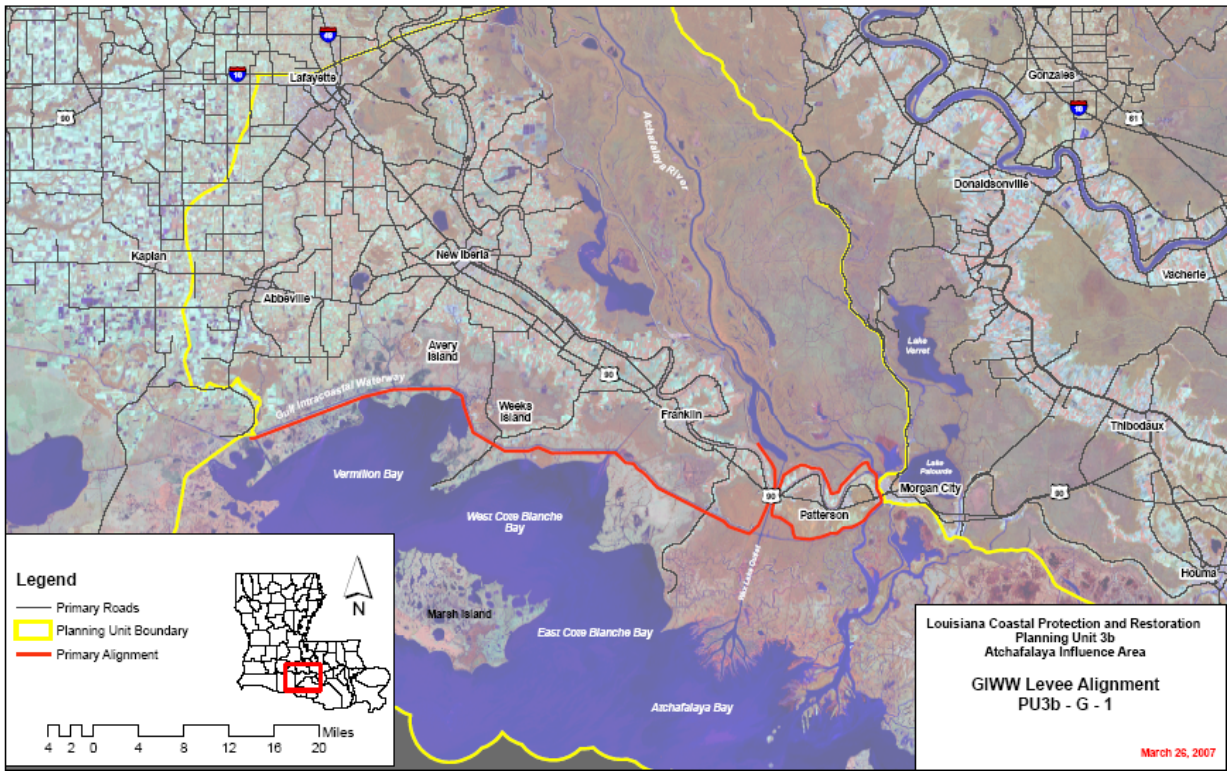

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1076 **Figure 21. Example Franklin to Abbeville Alignment from the Plan Formulation Atlas**
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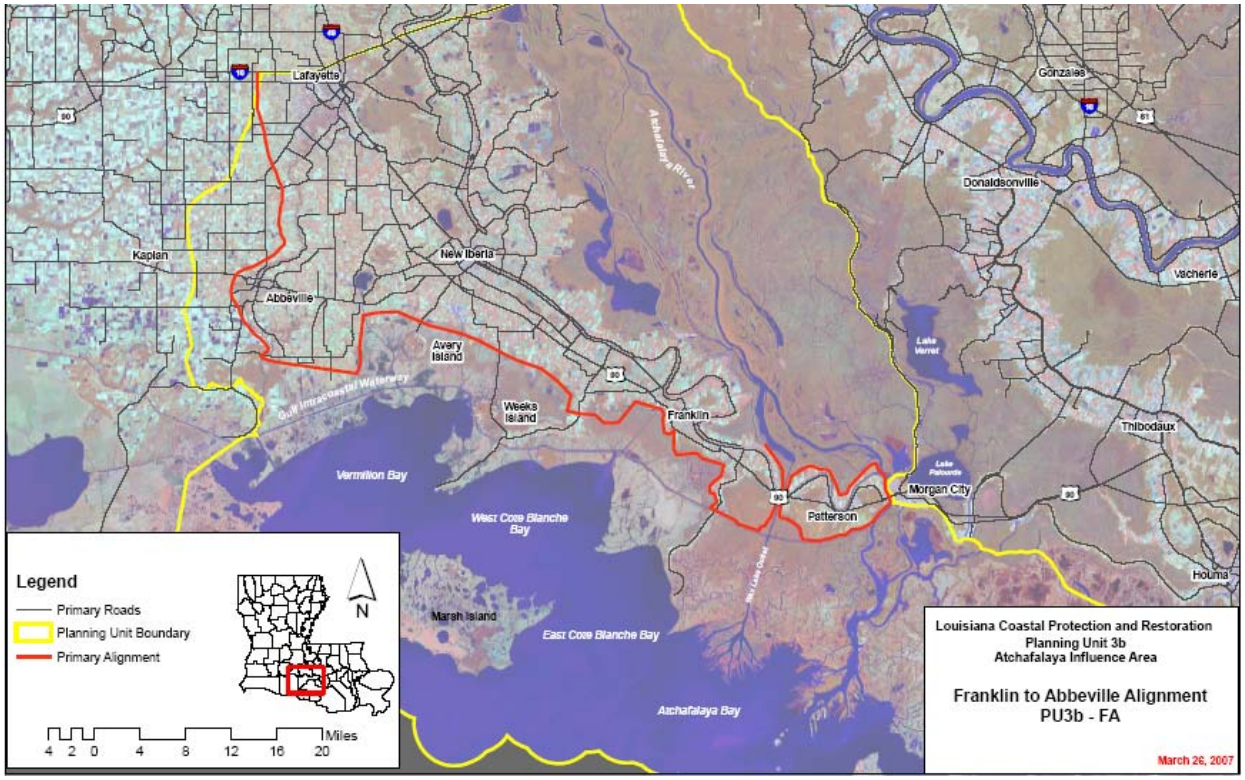

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Through the first tier of screening, in which preliminary construction costs, constructability as well as direct environmental impacts were considered, the number of variations was screened to three. **Table 19** lists the variations of the levee alignments and describes why some alignment variations were eliminated from further consideration at this time.

Table 19. Initial Screening of Planning Unit 3b Structural Measures

Measure Code(s)	Pass/Fail	Comments
PU3b-G-1	Pass	Alignment that forms part of a continuous levee across all of South Louisiana.
PU3b-G-2	Fail	Captured in alignments 'G-1' and 'FA.' When comparing the 'G-2' alignment to the 'FA' alignment, 'FA' is the preferred alignment.
PU3b-FA and PU3b-State	Pass	The Franklin to Abbeville (FA) alignment is essentially same as the State Master Plan alignment.

Tier 2 – Initial Hydromodeling of Structural Measures

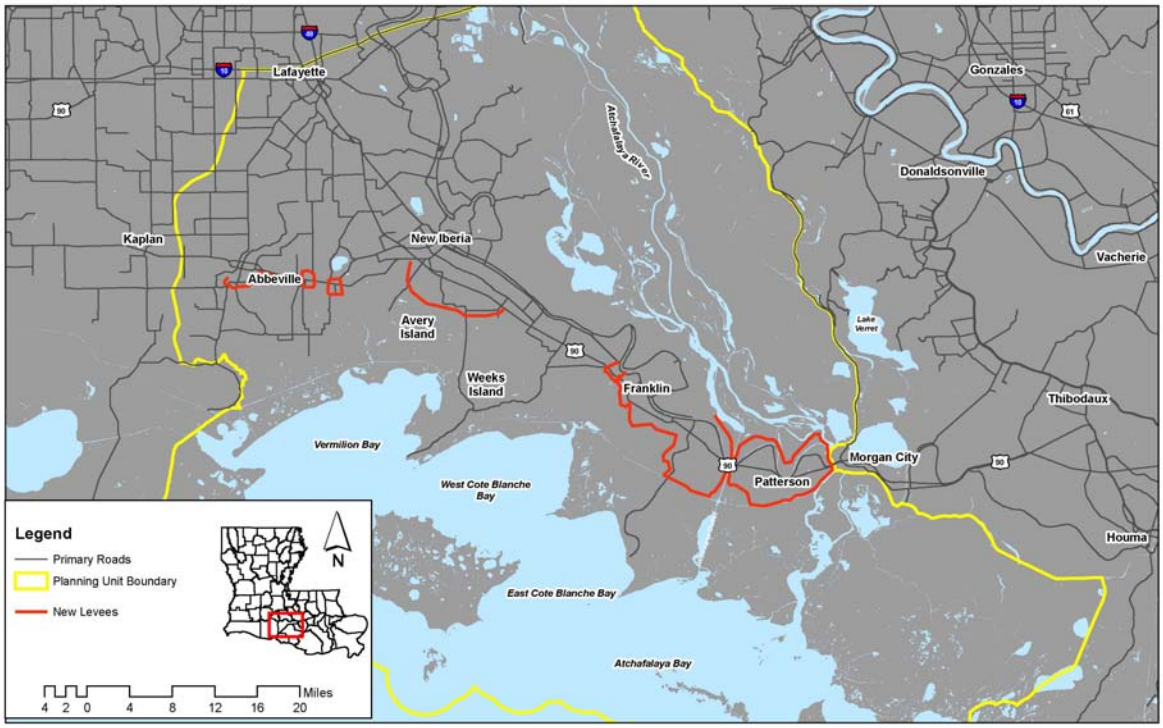
In addition to the initial screening evaluation, additional hydromodeling was necessary to resolve and further refine the possible structural measures in Planning Unit 3b. Remaining formulation issues included:

- Comparison of the GIWW and the Franklin to Abbeville alignment.
- Formulation of additional structural measures due to the dispersed population with isolated areas of higher density.
- Design level of risk reduction.

As a result of the high cost of a continuous levee (GIWW and Franklin to Abbeville alignments), a measure that includes a series of ring levees rather than a continuous levee was considered and evaluated. This resulted in a measure with ring levees in the west to protect the major population centers, with a continuous levee from Baldwin and across to the east. As a result of Tier 2 screening, the following three types of measures were carried to Tier 3:

- The GIWW alignment (similar to **Figure 20**);
- The Franklin to Abbeville alignment (similar to **Figure 21**);
- A series of ring levees around Patterson/Berwick, Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville (see **Figure 22 below**).

Figure 22. Reformulated Ring Levee Alignment



With the inclusion of different risk-reduction levels, name convention for the structural managements measures were revised slightly from previous screening nomenclature. **Table 20** describes the coding.

Table 20. Planning Unit 3b Codes used for Tier 2 and Tier 3 Screening

Code	Measure Code Description (e.g. PU3b-RL-100-1)
PU3b-	Planning Unit 3b
-G-	GIWW levee alignment
-F-	Franklin to Abbeville alignment (inland of the GIWW)
-RL-	Ring levee alignment
-100-	100-year design level
-400-	400-year design level
-1000-	1000-year design level
-1	Primary alignment for each plan strategy.

Tier 3 – Multi-Criteria Screening of Structural Measures

The Planning Unit 3b structural measures were then subjected to analysis using 100, 400, and 1000-year events. This resulted in the development of nine variations. These structural measures were then ranked using the multiple attributes previously described in **Table 1**.

Table 21 displays the ranking of the nine measures and the screening attribute values used to conduct the ranking.

Table 21. Planning Unit 3b Multi-Criteria Ranking of Measures

Measure	Screening Attributes												Total Value Score***	Rank
	Cost Effectiveness		Equiv. Annual Flood Damages		2075 Pop. Impacted 400-yr Event		Present Value Costs	Construction Period		Direct Impact- Wetlands				
	Ratio*	Value**	$ Million	Value**	# People	Value**	$ Million	Value**	Years	Value**	Acres	Value**		
PU3b-G-100-1	33.61	0.35	353	0.64	11,793	0.16	13,876	0.47	10	0.71	2,296	0.29	**2.62**	**1**
PU3b-F-100-1	35.48	0.37	411	0.75	67,980	0.90	12,589	0.43	10	0.71	2,466	0.31	**3.46**	**2**
PU3bF-400-1	62.15	0.64	411	0.75	8,053	0.11	22,069	0.75	12	0.86	3,878	0.49	**3.58**	**3**
PU3b-G-400-1	56.14	0.58	385	0.70	2,964	0.04	21,403	0.73	12	0.86	5,506	0.69	**3.59**	**4**
PU3b-RL-100-1	43.93	0.45	528	0.96	75,917	1.00	10,433	0.35	10	0.71	940	0.12	**3.60**	**5**
PU3b-RL-400-1	71.63	0.74	529	0.96	40,911	0.54	16,966	0.57	12	0.86	1,702	0.21	**3.89**	**6**
PU3bF-1000-1	91.07	0.94	444	0.81	7,706	0.10	29,280	0.99	14	1.00	5,188	0.65	**4.49**	**7**
PU3b-RL-1000-1	97.13	1.00	549	1.00	38,308	0.50	21,092	0.71	14	1.00	2,218	0.28	**4.50**	**8**
PU3b-G-1000-1	85.63	0.88	421	0.77	2,870	0.04	29,519	1.00	14	1.00	7,987	1.00	**4.69**	**9**

Indicates structural measure is included in the overall set of LACPR alternatives to be evaluated.

* Cost Effectiveness Ratio = Total Present Value Costs /Average Annual Equivalent Risk Reduction

** Value is the normalized value for the attribute where a value of 1.00 represents the greatest is the largest (lower is better)

***Total of Normalized Values (lower is better)

Based on the multi-criteria screening analysis and in consideration of the need to investigate a range of different ways to reduce the risk of hurricane storm damages the following four structural measures were selected for the final array (listed in order of rankings):

PU3b-G-100-1: This measure ranked 1st among the structural measures in Planning Unit 3b. This measure performed considerably better than the other structural measures in PU3b. Although it is not the least cost, it was the most cost effective and protected the greatest number of people.

PU3b-F-100-1: This measure ranked 2nd among the structural measures in Planning Unit 3b. This measure is less costly than PU3b-G-100-1 but protects less people.

PU3b-F-400-1: This measure ranked 3rd among the structural measures in Planning Unit 3b. This measure ranked highest among all the measures designed to provide protection against the 400-year hurricane event PU3b-G-400-1 was more cost effective and protected more people, but the impacts to wetlands was much greater.

PU3b-RL-100-1: This measure ranked 5th among the structural measures in Planning Unit 3b. This measure has the least cost and has the least impact to wetlands.

PU3b-RL-400-1: This measure ranked 6th among the structural measures in Planning Unit 3b. This measure is included to provide a comparison between the management measures

PU3b-F-1000-1: This measure ranked 7thamong the structural measures in Planning Unit 3b. This measure is the highest ranking measure designed to that provide protection against the 1000-year hurricane event, however it is not the least expensive.

Structural Measures to be included in Planning Unit 3b Alternatives

Below is the array of options to be included as structural components of alternatives to be considered for detailed analysis for Planning Unit 3b. These structural measures allow for comparison of risk reduction improvements in Planning Unit 3b. These structural components will be combined with coastal restoration and nonstructural measures to provide comprehensive risk reduction.

Continuous Levee Alignments:

PU3b-G-100-1: Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the GIWW west to the boundary of Planning Unit 4 at the 100-year design level.

PU3b-F-100-1: Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 100-year design level.

PU3b-F-400-1: Raise ring levee around Patterson/Berwick to 400-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 400-year design level.

PU3b-F-1000-1: Raise ring levee around Patterson/Berwick to 1000-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 1000-year design level.

Ring Levee Alignments:

PU3b-RL-100-1: Raise ring levee around Patterson/Berwick to 100-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 100-year design level.

PU3b-RL-400-1: Raise ring levee around Patterson/Berwick to 400-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 400-year design level.

Planning Unit 4

The following sections provide details on the tiered screening of measures and alignments for Planning Unit 4. Planning Unit 4 extends from the western bank of Freshwater Bayou westward to the Louisiana/Texas state line in Sabine Lake, and from the Gulf of Mexico in the south to the northern boundary located just north of Sulphur, Lake Charles, and Interstate Highway 10. The planning unit includes all or parts of Vermilion, Cameron, Acadia, Jefferson Davis, and Calcasieu Parishes. The Chenier Plain extends from Freshwater Bayou westward to Sabine Pass, and is influenced by three interconnected rivers and marine processes. There are two major hydrologic basins in the Cheniers: the Mermentau Basin and the Calcasieu/Sabine Basin. The navigation channels of the Chenier Plain are the Sabine/Neches Waterway, Calcasieu River Navigation Channel, the GIWW, Mermentau Ship Channel, and Freshwater Bayou Canal, and all of them influence hydrology throughout the planning unit.

This planning unit represents approximately 250,000 residents, or 12 percent of the population, within the planning area. Major population centers within the planning unit include Duson, Rayne, Crowley, Estherwood, Mermentau, Jennings, Welsh, Iowa, Lake Charles, Sulphur, Vinton, Kaplan, Morse, and Lake Arthur.

Significant oil and gas facilities, chemical plants, and other coast-related industries are located in the Lake Charles area, Lafayette, Hackberry, Vinton, and smaller communities. Agricultural land and cattle land are the primary land uses in much of Planning Unit 4.

Tier 1 – Initial Screening of Structural Measures

Five primary strategies were identified for structural risk reduction in Planning Unit 4. They include ring levees, GIWW alignment, Highway 82 alignment, ten-foot contour alignment and the State Master Plan alignment. The ring levees provide risk reduction to concentrated assets in communities such as Abbeville, Kaplin, Vinton, Sulphur, Westlake, Lake Charles and Gueydon. The GIWW alignment would provide a continuous levee from Patterson/Berwick to Abbeville

along the GIWW while the Highway 92 alignment would provide a continuous levee along the highway from Vinton to Abbeville. The ten-foot contour alignment would provide a nearly continuous levee along the ten-foot contour from Texas to Abbeville. The State Master Plan alignment is a hybrid between the GIWW and the Ring Levee alignments. Within these five strategies, six variations were identified. **Table 22** describes the codes used in the Plan Formulation Atlas and for Tier 1 screening for measures in Planning Unit 4**. Figures 23** through **26** show examples of the various alignments.

Table 22. Planning Unit 4 Codes from Plan Formulation Atlas used for Tier 1 Screening

Code	Measure Code Description (e.g. PU4-RL-2)
PU4-	Planning Unit 4
-RL-	Ring levee alignment
-G	GIWW levee alignment
-H	Highway 82 alignment
-C	10-foot contour alignment
-State	Alignment that was part of the preliminary draft State Master Plan
-#	Variations to the primary alignments (if applicable)

Figure 23. Example Ring Levee Alignment from Plan Formulation Atlas

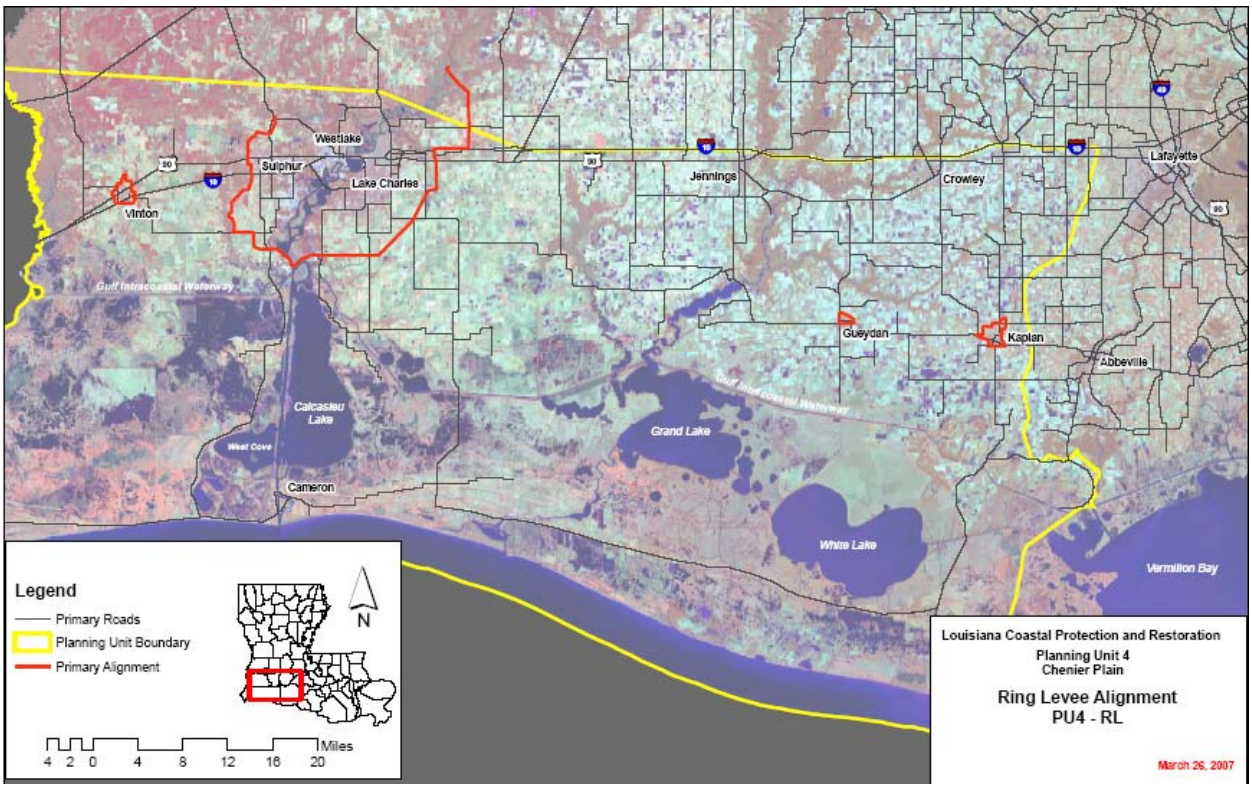


Figure 24. GIWW Alignment from Plan Formulation Atlas

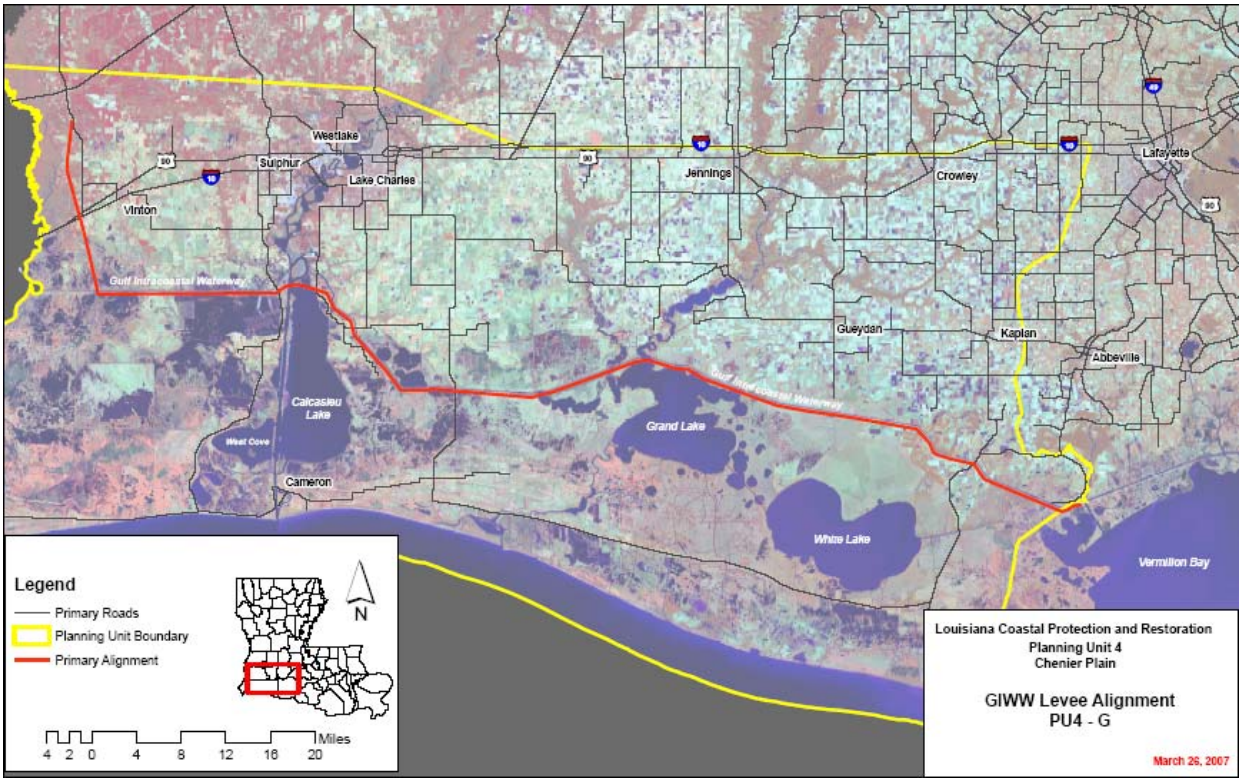


Figure 25. Highway 82 Alignment from Plan Formulation Atlas

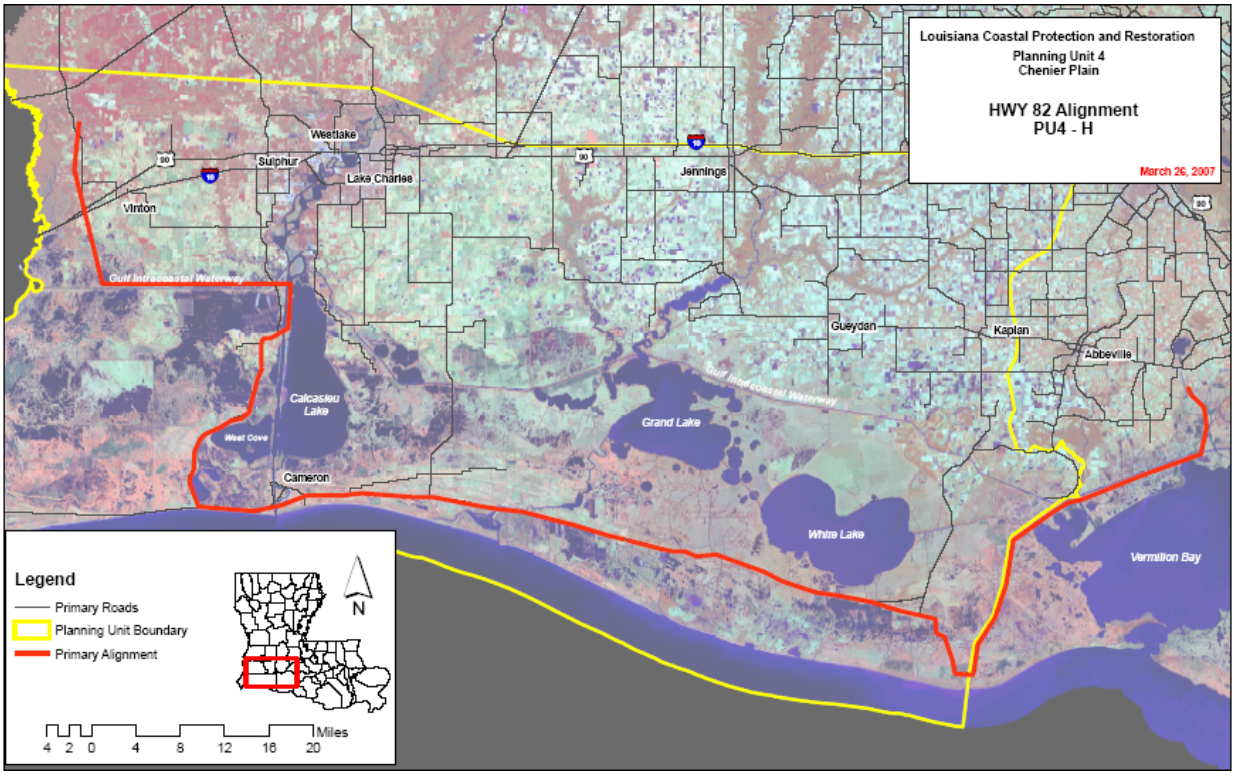
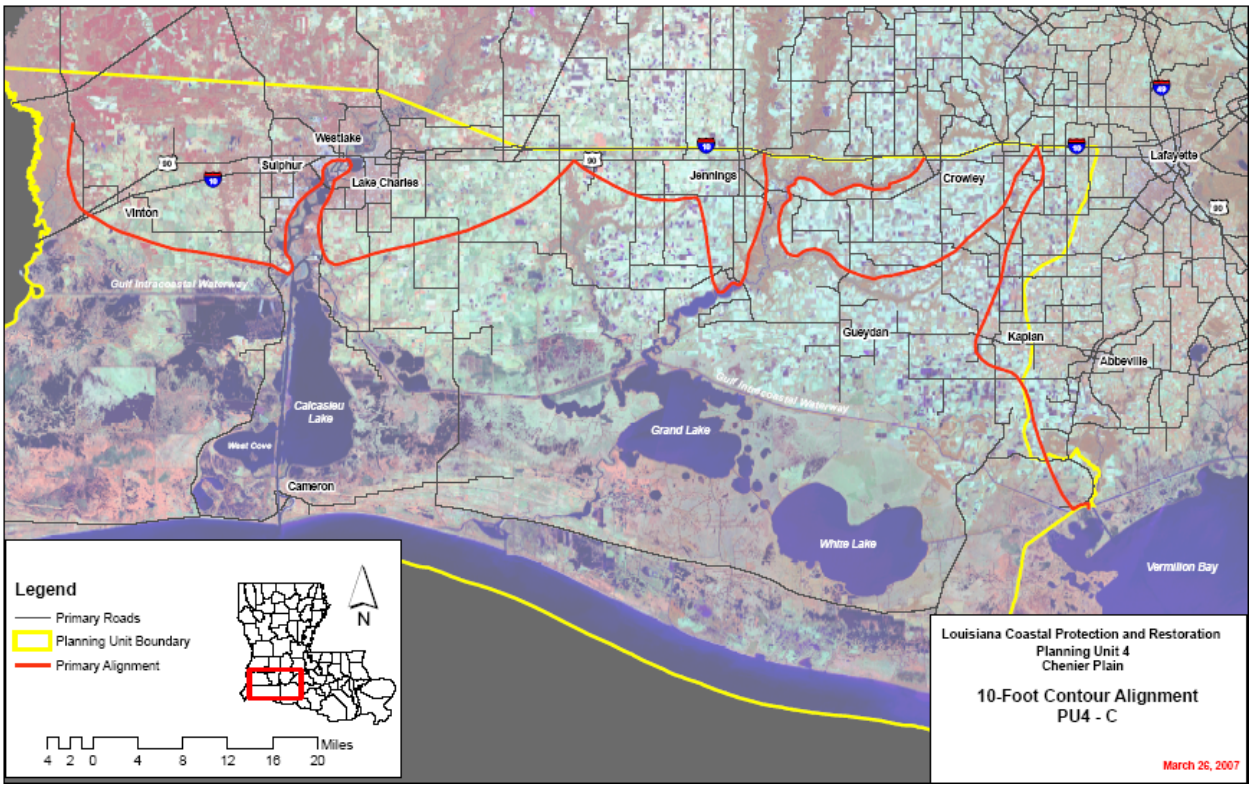


Figure 26. 10-Foot Contour Alignment from Plan Formulation Atlas



Through the first tier of screening, in which preliminary construction costs, constructability as well as direct environmental impacts were considered, the number of variations was screened to three. **Table 23** lists the variations of the levee alignments and describes why some alignment variations were eliminated from further consideration at this time.

Table 23. Initial Screening of Planning Unit 4 Structural Measures

Measure Code(s)	Pass/ Fail	Comments
PU4-RL	Pass	Consistent with State's ring levee concept.
PU4-RL-2	Fail	Ring levee concept captured better by 'RL' above; this version has excessive costs and would exacerbate Vermilion River flooding in comparison to 'RL.'
PU4-G	Pass	Forms part of a continuous levee from border to border for evaluation of a comprehensive "Category 5" structural option.
PU4-H	Fail	Strong local opposition; high cost; environmental concerns such as wetland impacts and drainage problems (e.g. trapping saltwater after a storm).
PU4-C	Fail	Long length (high life-cycle costs); environmental concerns such as wetland impacts and drainage problems (e.g. trapping saltwater after a storm).
PU4-State	Pass	Hybrid approach using both a ring levee and a GIWW alignment.

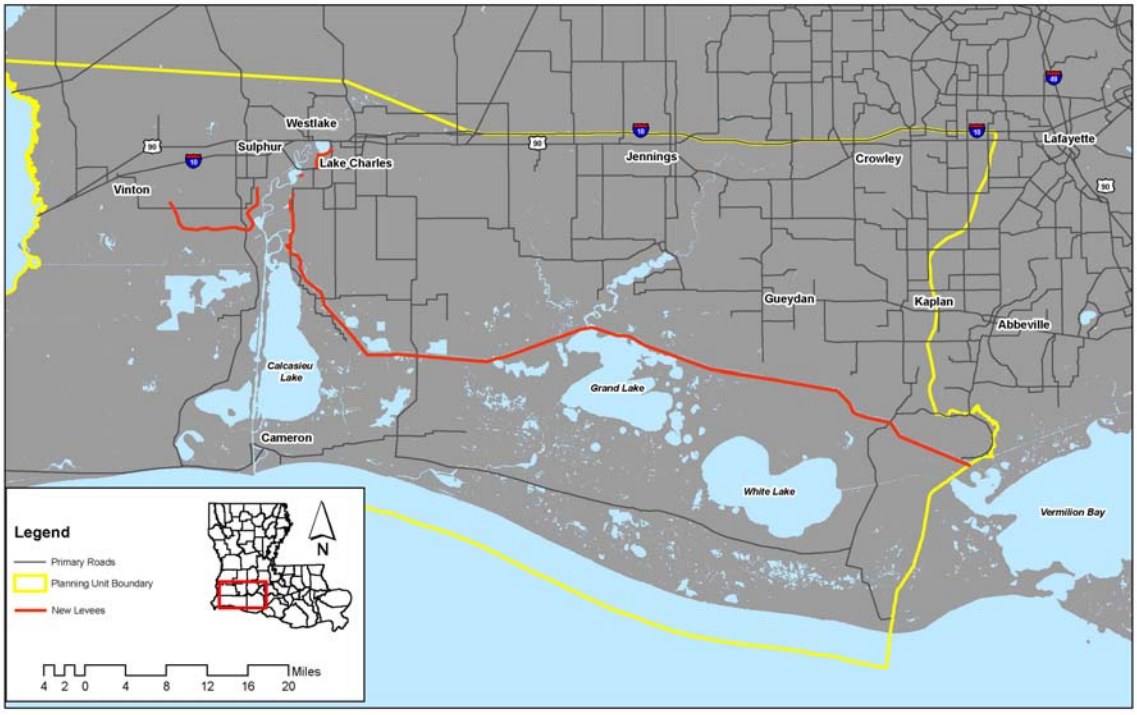
Tier 2 – Initial Hydromodeling of Structural Measures

In addition to the initial screening evaluation, additional hydromodeling was necessary to resolve and further refine the possible structural measures in Planning Unit 4. Remaining formulation issues included:

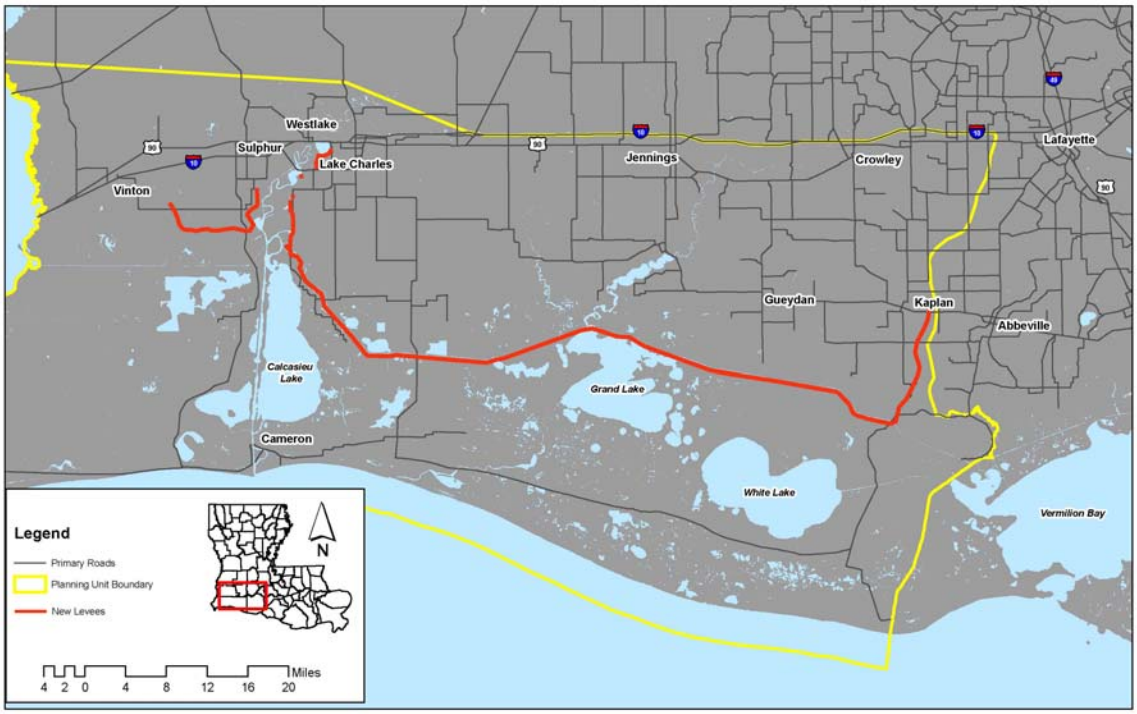
- Comparison of the various GIWW alignments.
- A continuous levee or a series of ring levees to protect isolated areas.
- Design level of risk reduction.

The hydromodeling results revealed that the measures needed to be reformulated based on areas impacted and the location of concentrated assets. This reformulation resulted in variations on the two structural strategies, including a levee along the GIWW that runs south of the majority of population-at-risk from flooding (**Figure 27** and **Figure 28**) and a series of site specific ring levees to protect major population centers (**Figure 29**).

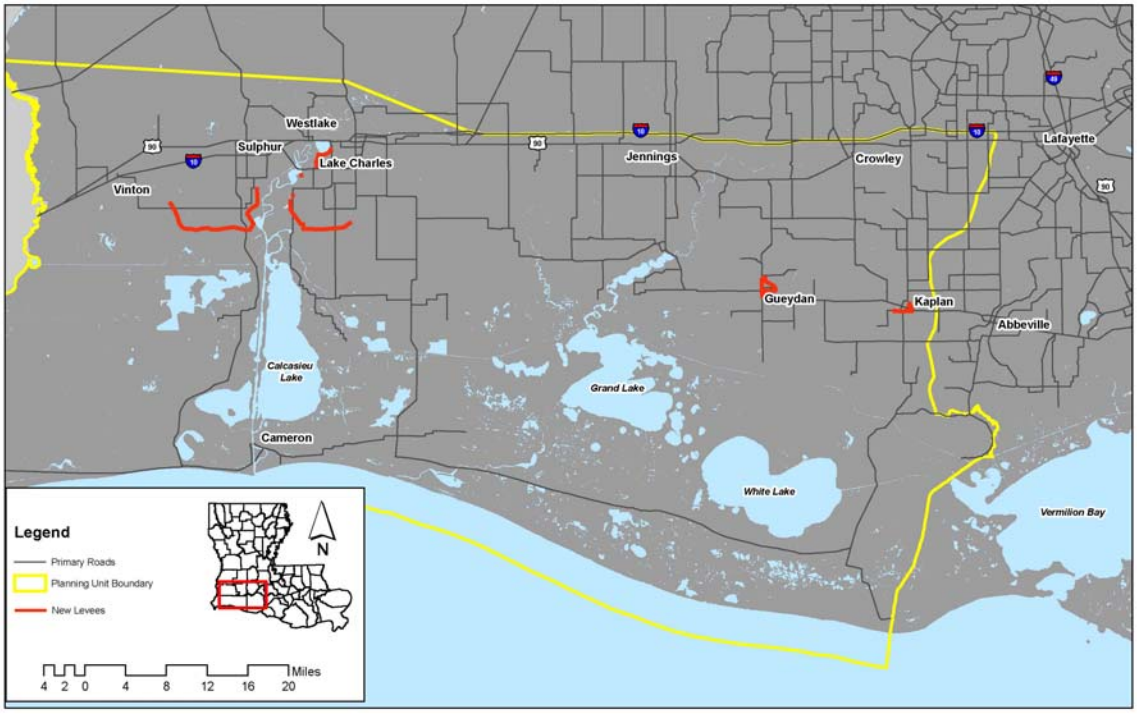
Figure 27. Reformulated GIWW Alignment (with tie in to Planning Unit 3b).



1267 **Figure 28. Reformulated GIWW Alignment (stand alone for Planning Unit 4).**



1268
1269 **Figure 29. Reformulated Ring Levee Alignments.**



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With the inclusion of different levels of risk reduction, name convention for the structural managements measures were revised slightly from previous screening nomenclature. **Table 24** describes the coding.

Table 24. Planning Unit 4 Codes used for Tier 2 and Tier 3 Screening

Code	Measure Code Description (e.g. PU4-RL-100-1)
PU4-	Planning Unit 4
-G-	GIWW levee alignment
-RL-	Ring levee alignment
-100-	100-year design level
-400-	400-year design level
-1000-	1000-year design level
-1	For the 'G' alignments, the primary alignment follows the GIWW across the planning unit boundaries.
-2	GIWW alignment with tieback to high ground near Kaplan.
-3	GIWW alignment with the levee set at a height of 12 feet.

Tier 3 – Multi-Criteria Screening of Structural Measures

The Planning Unit 4 structural measures were then subjected to analysis using 100, 400, and 1000-year events. This resulted in the development of 11 variations. These structural measures were then ranked using the multiple attributes previously described in **Table 1**.

Table 25 displays the ranking of the 11 measures and the screening attribute values used to conduct the ranking.

Table 25. Planning Unit 4 Multi-Criteria Ranking of Measures

Measure	Screening Attributes												Total Value Score***	Rank
	Cost Effectiveness		Equiv. Annual Flood Damages		2075 Pop. Impacted 400-yr Event		Present Value Costs		Construction Period		Direct Impact-Wetlands			
	Ratio*	Value**	$ Million	Value**	# People	Value**	$ Million	Value**	Years	Value**	Acres	Value**		
PU4-RL-100-1	16.37	0.06	565	0.83	44,284	0.58	2,374	0.11	10	0.71	88	0.02	**2.31**	**1**
PU4-RL-1000-1	106.66	0.39	679	1.00	49,117	0.64	3,299	0.15	14	1.00	99	0.02	**3.20**	**2**
PU4-G-400-3	76.57	0.28	571	0.84	46,102	0.60	10,692	0.50	10	0.71	2,483	0.44	**3.38**	**3**
PU4-RL-400-1	105.38	0.39	681	1.00	76,409	1.00	3,057	0.14	12	0.86	95	0.02	**3.40**	**4**
PU4-G-100-2	75.29	0.28	568	0.83	73,948	0.97	10,736	0.50	10	0.71	1,763	0.31	**3.60**	**5**
PU4-G-100-1	73.51	0.27	562	0.83	73,304	0.96	10,907	0.51	10	0.71	2,221	0.39	**3.67**	**6**
PU4-G-400-2	111.49	0.41	567	0.83	27,530	0.36	15,946	0.74	12	0.86	2,939	0.52	**3.72**	**7**
PU4-G-400-1	109.15	0.40	562	0.82	26,439	0.35	16,209	0.75	12	0.86	3,719	0.66	**3.84**	**8**
PU4-G-1000-3	271.63	1.00	669	0.98	47,299	0.62	11,119	0.52	10	0.71	2,485	0.44	**4.27**	**9**
PU4-G-1000-2	156.40	0.58	577	0.85	26,968	0.35	20,861	0.97	14	1.00	4,277	0.76	**4.50**	**10**
PU4-G-1000-1	155.77	0.57	572	0.84	25,885	0.34	21,546	1.00	14	1.00	5,625	1.00	**4.75**	**11**

Indicates structural measure is included in the overall set of LACPR alternatives to be evaluated.

* Cost Effectiveness Ratio = Total Present Value Costs /Average Annual Equivalent Risk Reduction

** Value is the normalized value for the attribute where a value of 1.00 represents the greatest is the largest (lower is better)

***Total of Normalized Values (lower is better)

Based on the multi-attribute screening analysis and in consideration of the need to investigate a range of different ways to reduce the risk of hurricane storm damages the following seven structural measures were selected for the final array (listed in order of rankings):

PU4-RL-100-1: This measure ranked 1st among the structural measures in Planning Unit 4. This management measure is the least costly and most cost effective management measure among structural measures considered.

PU4-RL-1000-1: This measure ranked 2nd among the structural measures in Planning Unit 4. This management measure provides protection to a greater population than PU4-RL-100-1 at a slightly higher cost. PU4-RL-1000-1 is the most cost effective management measure among the measures designed to provide protection against the 1000-year hurricane event.

PU4-G-400-3: This measure ranked 3rd among the structural measures in Planning Unit 4. This management measure is the most cost effective measure among the measures designed to provide protection against the 400-year hurricane event.

PU4-RL-400-1: This measure ranked 4th among the structural measures in Planning Unit 4. Although considerably less expensive than PU4-G-400-3, this measure provides structural protection to a significantly smaller population.

PU4-G-100-2: This measure ranked 5th among the structural measures in Planning Unit 4. This measure is included to provide a comparison between the management measures.

PU4-G-100-1: This measure ranked 6th among the structural measures in Planning Unit 4. This measure is included to provide a comparison between the management measures.

PU4-G-1000-3: This measure ranked 9th among the structural measures in Planning Unit 4. This measure is included to provide a comparison between the management measures.

Structural Measures to be included in Planning Unit 4 Alternatives

Below is the array of options to be included as structural components of alternatives to be considered for detailed analysis for Planning Unit 4. These structural measures allow for comparison of risk reduction improvements to communities in Planning Unit 4. For the Planning Unit 4 alternatives, these structural components will be combined with coastal restoration and nonstructural measures to provide comprehensive risk reduction.

GIWW (Continuous Levee) Alignments:

PU4-G-100-1: Construct a continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land at the 100-year design level. Alignment joins with similar alignment in Planning Unit 3b.

PU4-G-100-2: Construct a continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river

from the land at the 100-year design level. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.

PU4-G-400-3: Construct a continuous 12-foot levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land. May include small ring levees around parts of Lake Charles, Gueydan, and Kaplan to provide 400-year level of risk reduction. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.

PU4-G-1000-3: Construct a 12-foot continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land. May include small ring levees around parts of Lake Charles, Gueydan, and Kaplan to provide 400-year level of risk reduction. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.

Ring Levee Alignments:

PU4-RL-100-1: Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to the 100-year design level.

PU4-RL-400-1: Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to the 400-year design level.

PU4-RL-1000-1: Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to 100-year design level.

Summary

This appendix described the steps taken to screen structural risk reduction measures for the LACPR technical evaluation. The process started with a wide array of concepts gathered from previous studies as well as input from the State Master Plan and other stakeholders. The three-tiered screening process first eliminated measures that were either undesirable on their own merits or in comparison to similarly performing measures. The next step was to evaluate and reformulate the remaining measures using quantitative hydromodeling data. The final screening used multiple criteria to rank the structural measures to determine which should be carried forward into the set of alternatives to be evaluated for the overall LACPR effort.

The coastal restoration and nonstructural measures, which are part of the overall LACPR alternatives, were developed on parallel tracks. The formulation of those measures is described in the *Coastal Restoration Plan Component Appendix* and *Nonstructural Plan Component Appendix,* respectively.